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JOURNAL OF THE ROYAL SOCIETY OF ARTS

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FRIDAY, NOVEMBER 24, 1922.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

ONE-HUNDRED-AND-SIXTY-NINTH SESSION, 1922-1923.

NOTICES.

NEXT WEEK.

MONDAY, NOVEMBER 27th, at 8 p.m. (Cantor Lecture.) WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Brown Coal and Lignites." (Lecture I.)

WEDNESDAY, NOVEMBER 29th, at 8 p.m. (Ordinary Meeting.) MAJOR W. S. TUCKER, R.E., D.Sc., Signals Experimental Establishment, Woolwich, "The Hot Wire Microphone and its Applications to the Problems of Sound." ADMIRAL OF THE FLEET SIR HENRY B. JACKSON, G.C.B., K.C.V.O., D.Sc., F.R.S., will preside. (The paper will be illustrated with experiments.

SPECIAL MEETING.

MONDAY, NOVEMBER 13th, 1922; LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, in the Chair.

A paper on "The Strand and the Adelphi: Their Early History and Development" was read by Mr. JOHN SLATER, F.R.I.B.A., Member of the Council.

The paper and discussion will be published in the *Journal* of December 1st.

SECOND ORDINARY MEETING.

WEDNESDAY, NOVEMBER 15th, 1922; CAPTAIN W. E. NUTTALL, M.B.E., Chairman of the Technical Section, Papermakers' Association, in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Aguilar, Ponciano, Guanajuato, Mexico.
Graham, Captain H. A. R., London.
Koder, Samuel Sabattai, Malabar Coast, India.
Maclay, William Walter, M.A., C.E., Lee, Massachusetts, U.S.A.
May, Mrs. Emma Lilian, London.
Prasad, Tewari Balbhadra, M.L.C., Old Cawnpore, India.
Sanders, Cameron Oswald, Derby.
Stephens, Fred S., Calcutta, India.
Van Norden, Warner M., LL.D., New York City, U.S.A.

A paper on "The Action of the Beater in Paper making, with special reference to the Theory of the Beater-Bar-Fibrage, and its Application to Old and New Problems of Beater Design" was read by OVERINGENIEUR DR. SIGURD SMITH (Charlottenlund, Denmark).

The paper and discussion will be published in the *Journal* of December 8th.

INDIAN SECTION.

FRIDAY, NOVEMBER 17th, 1922; SIR THOMAS H. HOLLAND, K.C.S.I., K.C.I.E., LL.D., D.Sc., F.R.S., Rector of the Imperial College of Science and Technology, in the Chair.

A paper on "The Development of Water Power in India" was read by MR. J. W. MEARES, C.I.E., M.Inst.C.E., M.I.E.E., Member of the Institution of Engineers (India).

The paper and discussion will be published in the *Journal* of December 15th.

PROCEEDINGS OF THE SOCIETY.

FIRST ORDINARY MEETING.

WEDNESDAY, NOVEMBER 8TH, 1922.

LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, in the Chair.

THE CHAIRMAN delivered the following address:—

THE VALUE OF LOCK-OUTS AND STRIKES.

Last year Sir Philip Magnus, Chairman of the Examinations Committee, claimed that the Royal Society of Arts had succeeded in popularising commercial science all over the country, and mentioned that the entries for examinations had risen from 37,014 in 1914 to 60,332 in 1922.

Among the matters connected with "commercial science" importance has to be attached, not only to the application of machinery made of metals or woods or rubber and to the products and adaptations of the inventive genius of the human brain, but in all industrial concerns to the human factor, the use or abuse of the power behind the machine, that wonderful and complex sentient thing, man himself. If I speak not, as so many former Chairmen have done, of the history of inventions, the adaptations which have been made or are to be expected, the marvels which discoveries have revealed, it is because I would suggest that, on one occasion at least, notice at the present day seems due to this other factor, on which so much depends.

Owing to the needs and lessons of the war, a wave of interest and research has carried thought and knowledge very rapidly forward in consideration of the human factor. The questions of health and welfare and shorter hours, the lessening of fatigue, the proper movements applicable to the human body for quick and better production, ventilation and elimination of dust, lighting and heat, have all been discussed and are being examined with great zest and search for precision. Data are being collected for scientific deductions, and, with growing speed, empiricism or rule of thumb methods are discounted. Advocates examining different theories, from psychic and psychological phenomena to the proper movements for propulsion of a golf ball, flood the country with literary efforts, indicating that the "philosopher's stone" has been found. These movements show healthy growth, even if some of the shoots may require trimming. The general interest in such subjects is illustrated by the space given to them in the Press.

In a brief lecture I do not propose to deal with any of these sections, but to endeavour to say something, without any pretence of finding a philosopher's stone, on the dark cloud of strikes and lock-outs, which has continually shadowed efforts at reconstruction and retarded the progress of the country. If that could be done away with or dispersed, without sharp showers or heavy rainfall, a far more sunny period would be forthcoming for everyone. Of that cloud the small section to which I shall apply my remarks is limited to "The Value of Lock-outs and Strikes." Are they or have they been useful?

Although the leaders of Labour say much about the importance of the League of Nations, and the necessity of applying the covenants of that League to countries and international disputes, in addition to such powers of enforcement as the covenant contains, Labour has proved to be far more chary in applying the same principles to the minor disputes in industrial concerns within the ambit of any country. Article 12 of the Covenant lays down that "The members of the League agree that, if there should arise between them any dispute likely to lead to a rupture, they will submit the matter, either to arbitration or to inquiry by the Council, and they agree in no case to resort to war until three months after the award by the arbitrators or the report of the Council." Articles 14 and 15 develop the principle and, if war is resorted to, Articles 16 and 17 enact a drastic boycott, involving "severance of all trade and financial relations, the prohibition of all intercourse between the League Nationals and the Nationals of the Covenant-breaking State, and the prevention of all financial, commercial or personal intercourse between the nationals of the covenant-breaking State and the Nationals of any other State, whether a member of the League or not." There is further remedy in the recommendation of military, naval, or air-force to the members of the League to protect the covenants.

Whether they might be practicable or not, no such covenants, engagements or enforcements provide against war in industry. From 1896 to 1914 the only Act of Parliament was the Conciliation Act of 1896, permitting arbitration by agreement or an inquiry. There were and are in existence many voluntary Conciliation Boards, but with no power of enforcement by one party against the other. Under the stress of the war compulsory arbitration was indeed applied to certain industries, but others, in spite of the interdependence of all industries, were left free. Immediately after the Armistice compulsory arbitration was abolished, though the Act of 1896 was still continued, and machinery was supplied, under the Industrial Courts Act, 1919, for arbitration by agreement or for inquiry and report; and in certain cases for inquiry, at the discretion of the Minister, with or without consent by the parties. Even though this Permanent Court, not so much used as it might be, affords opportunity for peaceful decisions, there is no requirement of delay. Industrial warfare, by lock-outs or strikes, is easily commenced, and often with difficulty closed. Again I ask, Are they useful?

The question is not easy to answer, because a view generally accepted is that they have been and are of service, and that practical results are obtained. Thus, in a recent book, purporting to be a text book on the relations of Capital and Labour, it is said "Discontent, expressed in constant agitation, has, unfortunately, been of practical value; that is one reason why it is so rife in industry to-day. No substantial increases in wages or improvements in working conditions have, in the past, been conceded voluntarily by employers, but only after pressure by the Unions, subject, of course, to considerable qualifications in special cases. It is more or less inevitable that it should be so, having regard to the way in which the machinery of collective bargaining has been operated by both sides. Every time, when an increase of wages, or an improvement in conditions is demanded and refused, and then ultimately given under threat of a strike, it feeds the springs of future discontent, and confirms in the worker's minds the efficacy of agitation." This sweeping statement is not supported by the citation of concrete examples, nor is it mentioned whether the alleged "practical value" has been maintained or has been an equivalent for the loss, distress, and hindrance caused by lock-outs and strikes to the well being of the parties concerned, whether they care or not for the interests of other industries and persons affected by their action.

On the other hand, the 60 members of the Provisional Joint Committee constituted from employers and the principal trade unions, after an Industrial Conference in February, 1919, recorded their opinion that "Employers' organisations and trade unions should enter into negotiations for the establishment of machinery, or the revision of the machinery, *for the avoidance of disputes*," and various other pronouncements might be cited indicating that it is not every leader of organised unions who desires to attach "practical value" to such disputes.

Lock-outs and strikes are as old as the records of history. An early case of a lock-out of the sons of men is described in the 11th chapter of Genesis, and has led to

vast misunderstandings in the world, and an early strike by the Israelites against bad material, in the 5th chapter of Exodus, has had far reaching results, both to the strikers and to all other nations. The value of each may be a matter of debate till history ceases to be recorded. I am not going too strongly to appraise past history beyond my own ken, but may mention some salient points in our own country within the short period of a century.

In 1825, the Repeal of the Combination Laws, which for the first time expressly allowed to labour the right of collective bargaining and the power of withholding labour by concerted action, was obtained, not by reason of, but rather in spite of, strikes. The Repeal seems to have been due to the efforts of Francis Place, Joseph Hume, and J. R. McCulloch, working upon the principle of equality before the law, by means of a Committee of the House of Commons. On the other hand, in 1830-1832, the coal miners of Northumberland and Durham tried two years of rioting and strikes, leading to the use of troops, marines and cavalry. In the result, the union came to an end without gain of anything. Again, in 1830-4, the so-called "New Unionism" supported every kind of "ism" that idealists could invent, with the result that Trade Unionism scarcely survived after the signal failure of strike upon strike.

A generation later, the Blackburn and other cotton lists on which the gradual evolution of the basic piece work rates of the cotton trade is founded, were obtained by careful and patient work, and gradual proof of value. No strikes could settle such complicated details. The success of the methods then employed led to "Councils of Conciliation" in other trades, and offered contrast to the complete defeat of the engineers about the same time. The engineers were locked out in answer to a concerted threat of immediate action for the abolition of piecework and systematic overtime. As if in anticipation of the sudden strikes of 1911, they proposed general action upon matters involving many qualifications and adjustments capable only of settlement by close examination of detail. In the result they failed entirely.

In the winter of 1859, there was a great dispute in the London building trade. A nine hours' day was demanded, and the employers in answer, tried to impose a document of renunciation of the Union. They went too far; and had to withdraw, but the men did not gain the nine hours' day. In this dispute efforts upon both sides were wasted.

A few years later, in 1867, after a succession of petty strikes and lock outs, employers tried, on their side, the weapon of the "general lock-out," *i.e.*, a lock-out of a whole industry in order to bring in employees who in two or three firms had not accepted particular terms, which had been generally accepted. The men in some localities, particularly in Sheffield, answered by outrages and violence. The Government stepped in with a Royal Commission, the leaders of the Trade Unions joining in the demand for an inquiry. Nobody had gained anything by some years of quarrel. It may be possible that these lock outs and strikes caused Parliament to deal with the difficulties by which the public were affected. My own view is that the course of inquiry and the legislation of the years between 1867 and 1876 (including laws such as the Conspiracy and Protection of Property Act of 1875 and the Employers and Workmen Act of the same year, and the shortening of hours in certain trades by law in 1874) were far more due to the efforts of men like Mr. Frederic Harrison, who still lives, respected and honoured, Professor Beesly, Mr. Applegarth, Mr. Mundella and Mr. Cross, with the legal aid of Sir Henry James and Sir William Harcourt, than to the "practical value" of lock-outs and strikes. These men aimed at equality before the law, the recognition of collective bargaining by both employers and employed, and the treatment of violence and intimidation as part of the general criminal law.

It may be claimed that a nine-hours' day resulted in 1871 from the Sunderland strike of engineers, but unless my old friend and colleague, John Burnett, had been there and had tactfully used persuasion and skill, especially in the Press, to push through a half-opened door, it may be doubted whether the door would not have been slammed in the face of force. The sentiment of trade union leaders at that time may be summed up in the words of William Allan, the veteran Secretary of the Amalgamated Society of Engineers, when he said before the Royal Commission in 1867, "We believe that all strikes are a complete waste of money, not only in relation to the workmen, but also to the employers."

The early seventies showed a wave of prosperity and an increase in membership of trade unions, to be succeeded in 1879 by disastrous depression, through which trade unionism emerged, but with numbers much reduced. Many strikes had occurred, and everyone of them seems to have failed. Recovery had to be slow, and as for Parliament, it was occupied with Ireland and obstruction. In these years of trouble Socialist views gained ground, and have gradually gained greater strength; as if the passing economic circumstances of a few years were the determining factor for a complete change of the evolution of centuries and the vast developments of the previous half-century. It may be remarked that in these years some of our present politicians and of our present trade union leaders and economic authors, or their immediate pupils, gained their impressions and their schooling.

Then came the dockers' strike of 1889. It was led by Tom Mann and John Burns. At the present day Mr. Tom Mann still sometimes speaks or writes, and his views are known. Mr. John Burns is very silent, but when President of the Local Government Board, and responsible to the nation, he made a great speech on unemployment in 1910, and I am not aware that he has altered his opinions. Heralded by a strike of match girls, the strike showed that unorganised workers, who were not trade unionists, could, in some sense, organise rapidly, but it was not the strike and force which led to results, so much as the sympathy and help of the public when facts became known. The bare settlement brought the dockers' "tanner," but it was many years before more basic foundations for dock working were reached by inquiry and negotiations. In the same year negotiation brought an eight-hours' day and some wage increase to London gas workers, but a strike brought back in the South Metropolitan Gas Company a 12-hours' shift and a profit-sharing scheme, at which the strikers had not aimed, and which has practically endured in principle up to the present day.

The most salient results of the dockers' strike, aided by an improvement in trade, were indirect. It led to an increase in the number of trade unionists. It also gave a fillip to Socialist propaganda, the theory of State Socialism, and schemes of which Mr. and Mrs. Sidney Webb make the cautious remark: "Time and experience alone will show how far the empirical Socialism of the Trade Unionist of 1889, with its eclectic opportunism, its preference for municipal collectivism, its cautious adaptation of existing social structure, and its modest aspirations to a gradually increasing participation of the workmen in control, may safely be pronounced superior in practicability to the revolutionary and universal Communism of Robert Owen." There may be various opinions as to the "practical value" of these indirect results.

Other strikes coming to the front about this time can scarcely be called successful so far as the announced aims of the employees were concerned. The engineering strike and lock-out of 1897, against which Mr. George Barnes vainly warned his colleagues, was a complete failure for the employees. The cotton strike of twenty weeks, in 1893, led to a small advance in wages, but the employers gained a method of avoiding strikes by means of the Brooklands Agreement, for which the workpeople had never asked. In 1894 employers broke up the boot and shoe trade agreement, but it was soon revived with less formal rules and an independent umpire. A four months' coal strike in 1893 only led to reduction of wages, with some provision for a minimum wage.

This series of disputes, hurting the public, bringing little or no advantage to the workpeople, and harassing trade union leaders, may have been a factor in preventing opposition to the meagre power of inquiry legislatively granted by the Conciliation Act of 1896, but does not seem to have produced many other results. Up to the period of the war the Conciliation Act was the only Act, and that not at first used, which could mitigate the damage of protracted disputes or hinder threatened outbreaks, but the work done under it subsequently became an element in affording example for the numerous boards of arbitration and conciliation which developed in so many industries.

I now come, after having dealt with events of which I have only read or heard, to the period during which, either in or out of official employment, I have had inside knowledge of the course of events and the effects of lock-outs and strikes. In considering the question of the usefulness of strikes and lock-outs during this period, I propose to allude to a few of the principal strikes, without taking account of minor

strikes. These have been of many types and varieties, but I cannot attach any lasting importance to such strikes as those in the building trades over ½d. per hour more or less, and revision of working rules; or in the boot and shoe trades, over small questions on price lists. In some trades their incidence has been largely met, particularly in the boot and shoe trade, by the extension or improvement of working rules, which both employers and trade unions have endeavoured to effect with the express purpose of avoidance of disputes.

The Taff Vale dispute of 1900 became important owing to the litigation which led up to the Trade Disputes Act, 1906: but as a strike it was wholly unnecessary. There were complaints about conditions and wages, and the alleged victimisation of a signalman, who did not want to move to a box with higher pay but not so convenient to his home, and who found, after an illness, his own box and the proposed box had been filled up. The proposals of the Company had narrowed these questions to a negligible difference. The local committee then enlarged the claim by demand for recognition of the union, which was a matter for headquarters. The Company refused. The Union sent down Mr. Richard Bell, with instructions to bring the dispute to a speedy termination, and a reproof of the action of these men as "most condemnatory," because they had acted prior to obtaining the consent of the Executive Committee of the Society. Mr. Bell tried to prevent "blacklegs" from coming into the district, an introduction which would have further inflamed a wildly excited people. He found that he and his Society became subject to the law, for procuring persons "who had or might enter into any contracts with the plaintiffs to commit a breach of contracts." He and his Society had to find about £35,000 damages and costs over a strike which brought neither recognition of the union nor any material advantages to the men. This result crippled the Society for a long period. Was this strike useful because, years after, it was used as an argument in favour of the Trade Disputes Act, 1906?

Passing over the Nottingham lace trade and the variety artistes' disputes, and also the Irish strikes in Belfast, I come to the Railway dispute of 1907.

The effect of the Taff Vale judgment, and possibly of the Trade Disputes Act, had been a remarkable increase in the numbers of men who enrolled in the Railway Unions. The recognition which Mr. Bell could not wisely suggest in 1900 had come within sight in 1907, and in addition the "All Grades" movement, of which an eight hours' day and general increase of wages were the chief points, did not seem likely to be arranged without recognition and resulting discussion. In January, February and September, 1907, the railway companies would not admit requests for recognition, and also took no steps to consider other claims. They had no leader, and preferred the policy of being a bundle of withies rather than a single stick, which might be severed by one well directed blow. There was serious threat of a strike. A ballot gave 76,825 in favour of a strike, and 8,773 against a strike for the purpose of enforcing the programme, including the principle of recognition. No strike occurred, because the Government, pleading Germany and foreign affairs, stepped in. The threat of a strike and the imminence of a strike did certainly have the effect of Government action, which under the peculiar circumstances of the case met with acceptance. The Chairmen of the Railway Companies were interviewed by Mr. Lloyd George, the system of Conciliation Boards was established, but the policy of separate entities was still continued. Whether a strike would have gained the object in view must be a matter of conjecture. All that can be said is that the railway employees gained a great deal without recourse to a strike. My own impression, formed from close knowledge in my office as head of the Railway Department of the Board of Trade at that time, is that they gained far more than any strike, with inevitable alienation of public sympathy, could have got for them, and that Mr. Bell was very wise in accepting, and persuading his colleagues to accept, the settlement then effected.

Government intervention by Mr. Lloyd George, the particulars of which I do not know, failed in a cotton dispute, a great strike of engineers on the North East Coast, and another of shipwrights and joiners on the north-east coast. His successor, Mr. Churchill, brought the parties together and they settled by themselves, agreeing in the settlement upon machinery for dealing with differences between employers and workmen, a result which does not indicate desire

for lock-outs and strikes by the leaders of either employers or employed.

In 1909 my term of office as Comptroller General of the Commercial, Labour and Statistical Departments of the Board of Trade, and subsequently as Chief Industrial Commissioner, began, and all disputes came under my immediate cognizance. In that year of 1909 a very serious dispute arose in the mining industry of Scotland, over a proposed reduction of wages and the minimum wage. If I may be allowed to mention a personal incident, it would be that my daughter possesses a beautiful silver porringer presented by the coal owners and coal miners of Scotland, in remembrance of her christening, which I was unable to attend owing to the crucial moment being then in the balance, namely, strike or no strike; and there was no strike. The coal owners offered arbitration, which was refused. The great trouble was that unless the dispute was settled, the miners of England and Wales had managed to pledge themselves to come out in sympathy. That meant a national coal strike. The second trouble was that some of the Scottish leaders had ulterior views, which became more generally known in 1917 and 1919. In the result Mr. Smillie was over-ruled by his Executive, and a settlement was effected by means of conciliation. When at a later date, in 1917, Mr. Smillie seemed to be on the way to the achievement of some of his claims, he suggested to me that he was not sure he had been right in agreeing to this settlement, but the fact was he never did agree. He was over-ruled and loyally carried out the terms of the settlement after it had been made. I am not going to argue whether it is reasonable for a man to upset the commerce of his country and thousands of homes in favour of hypothetical theories founded on the schooling by a grandson of Karl Marx, but I do say that unless dreams of the future may be a justification for a disastrous stoppage on a side issue, that side issue could have been fairly settled by any sensible arbiter upon the terms finally suggested and accepted without the grave risk of a national coal stoppage.

In the following year of 1910 most of the strikes could have been avoided, if there had been less injured vanity on the part of one or two trade union leaders in organised trades, and if there had been better organisation in trades generally considered to be organised. Of the first class the outstanding case was a cotton strike arising among the cardroom operatives over the displacement of a single man. The strike could have been avoided if the secretaries on both sides had followed the principles of the procedure laid down in The Brooklands Agreement, even if the particular type of case was not expressly governed by that Agreement. It was settled with some difficulty by conciliation. Fortunately this kind of case is rare, and may generally be avoided by either more explicit rules or the existence of an executive strong enough to over-rule the idiosyncrasies of individuals.

Of the second class there were several strikes. The Northumberland miners refused at first to follow the advice of their executive and of the Miners' Federation of Great Britain over the general conditions agreed with the coal owners to be observed under the Coal Mines' Regulation Act. The boiler makers refused to accept control by their leaders, went in for sporadic strikes, and were finally locked out. In the result, the method of settling disputes was revised and expedited. The miners of the Cambrian Combine, striking in sympathy over a price list at one pit, refused to accept a provisional settlement of the chairmen of the two sides of the South Wales Miners' Conciliation Board, advice given at Conciliation meetings, and the demand of the Miners' Federation of Great Britain. They were on strike for eleven months, and then went in on terms suggested by me eight months before resumption of work, only to find upon trial that these terms were satisfactory.

In fact, Mr. Philip Snowden (then M.P.), was correct in his comment that "the year 1910 had been an exceedingly trying time for all who have had any responsibility for the management of trade unions, and the direction of the Labour movement. The men connected with a number of important trade unions have shown a good deal of dissatisfaction with the actions of their responsible officials, and this dissatisfaction has expressed itself in some cases in rebellion against the agreements entered into by the Union Executive and in unauthorised strikes. . . Discipline in Trade Unionism is too vital a thing to be injured by violation, and, though an occasional irresponsible movement may succeed, such a practice must, if frequently adopted, be destructive of collective bargain-

ing and of trade unionism itself ; for no executive could retain office if its authority were not respected.'' If that comment be correct, the type of strikes to which allusion is made, would not be deemed of value by trade union leaders.

I now come to the year 1911, but do not propose to deal with its strikes in detail. Any reader who chooses can find an account of some of the principal disputes in my book ''Industrial Problems and Disputes,'' published by John Murray. There were strikes in almost every trade in this year or in 1912. There had been improvement in trade, but no general increase of wages. Large sections of work-people had low pay, while prices were rising. Employers suggested they ought to have time to recover from lean years before considering general advances. The shipping and port interests had employers within their ranks opposed to any concessions, and to any bargaining with unions or at conciliation boards. Some unions had been improving organisation, and had unexpected sympathetic support from masses of unorganised workpeople, amongst whom new leaders sprang up, unaccustomed or unwilling to negotiate, and sometimes knowing little of the business which they purported to represent.

The trouble began with seamen and firemen at Southampton, supported by dock labourers and other transport workers. It was followed by an upheaval of seamen and firemen, followed by all grades of transport workers at Hull, and then Liverpool and Manchester blazed up. At Manchester there were 23 unions and a number of unorganised men all pledged together not to return to work till the claims of all sections were satisfied or arranged. London followed, the men being bound together by a similar pledge. The capital came within measurable distance of a meat and butter famine, and the docks were at a complete standstill. The Liverpool shipowners tried a general lock-out of all cargo workers, but it did not succeed, and following upon a small strike of a section of railwaymen in that city, the Railwaymen's Societies sent an ultimatum to all the railway companies demanding consent within 24 hours to meetings of representatives of the unions with representatives of the companies, for negotiation of a settlement of the matters in dispute affecting the various grades. There followed a national strike, in which Mr. Lloyd George used the Morocco Crisis as a reason for the appointment of a small committee of two general managers to act on behalf of all the railways. At a later stage, Parliament had to intervene on behalf of the consumers by an unanimous resolution that conferences should be held to discuss the best mode of giving effect to a report of the Royal Commission which had been appointed to consider the matters of dispute, and ultimately the report with some modifications was maintained, together with the principle of negotiations with the railway companies as a body. The year closed with the dockers' and carters' strike at Dundee, in which the closing of the jute mills was involved.

It would be difficult to say that there was no value in the strikes and lock-outs of 1911. They did result in increase of wages, often too long delayed, to some classes of workpeople. They also gave an increased belief in their strength to many classes, particularly unorganized classes. They led to methods of negotiation in trades where such methods either had not existed or did not exist in a form accepted by the majority of persons engaged in the industry. On the other hand there was great loss and suffering to all classes of the community, serious ill-feeling, a prolongation of disputes for unnecessary periods, and the causes, though mainly economical, were often trivial and led to an undue position of sections of workpeople which afterwards gave rise to further disputes and friction, both between employers and employed, and between different bodies of the employed. Labour is very jealous of undue change in relative positions. Further, nearly all the disputes were finally settled by compromise, and many by intervention, which, given the spirit to settle, might have effected the actual results without the great upheaval.

As to recognition, that can generally be gained where organisation is sufficiently strong to justify the claim of particular men to speak as representatives of a trade. When recognition is obtained, and leaders are vested with power of bargaining, a bad sign of leadership is to insist on a strike because leaders have not entirely succeeded in attaining all their aims. The liking of young men for a fight, the rise of undisciplined members of a union, may be excuses for strikes, but are proofs of the absence of discipline and power of leadership

rather than evidence of the value of strikes.

As if the troubles of 1911 had not been enough to enable industries to gauge something of the value of strikes, the year 1912 opened with a great cotton stoppage over the principle of non-union and union labour, incurred by an absence of practical common sense, and a strike of transport workers on the Clyde, founded on the belief that the strike weapon was omnipotent, and marked by the ignorance of new leaders as to the real desires of the workers. Then came the coal strike. In this instance again it is difficult to assess the value of the strike. The miners by the intervention of the Government and an Act of Parliament got the principle of a general minimum wage established by law, but they also forced the employers to unite, and led the way to a succession of quarrels, which still leave the coal trade in a quandary. The Federated Area had been prepared to accept the principle of the minimum, and if the miners had not pressed for so high a rate at first, the principle could have been adopted in that area, and the increase of the rate, if it was insufficient, obtained at a later date. If by agreement in that area it had been started, other districts, some of whom were not averse to it, would have been bound to follow, and very possibly Scotland and even South Wales, whether they would have waived existing agreements or not, would have had great difficulty in effecting any new agreements at the close of the old, without admission of the principle.

A London transport strike followed, lasting from May to August, and involving about 100,000 men. This long strike was most ineffective. It began by an attempt to force the Union ticket. When that failed, the suggested reasons degenerated into bickerings over alleged breaches of agreement of the most trivial character. Five Cabinet Ministers butted in, with the most signal failure. An attempt at a National strike also failed, and finally the strike petered out on a renewed assurance by Lord Devonport that he would denounce any employer who broke the agreements of the Port.

I now come to the year before the war, 1913, noticeable by an outburst in the Midlands, mainly economic, and the Larkin disturbances in Ireland. In the Midlands the trouble began with a strike of girls. The flame soon spread. The employers were not united, and owing to the diversity of trades, found difficulty in taking united action. For the same reason they had not generally drawn any lesson from the previous two years and its probable effect upon their workpeople. After a protracted struggle the disputes ended in recognition of the Workers' Union, some concessions, and a good agreement for dealing with disputes in the future. A little vision might have led to a similar result without the fight. Ireland was quite different. In Ireland economic trouble of long standing proved a fertile soil for syndicalist aims, conducted with lack of good generalship and of sane judgment in practical methods for achieving tangible results. The Trade Unions of England gave aid out of sympathy, but broke off almost in disgust. Mr. Larkin had attempted more than he could achieve, and so far as improvement for the workpeople was concerned, I do not think that any advantage was gained.

Coming to 1914; in the month before the war schemes were in hand for a movement during the autumn in favour of the eight-hours' day and various other claims which might have led to considerable disturbance. In August, 1914, these clouds temporarily vanished, and a different aspect of affairs came into being, but not without tinge of the feelings and opinions engendered by the disputes of the past, and the supposed value of the strike.

During the war there were few, if any, lock-outs, andthere should have been no strikes. The period being abnormal, I propose only to say a few words upon general points. The first point is that when the nation desired to co-operate and to succeed, everyone at the commencement of the war desired to stop disputes. Internal faction was by instinct recognised as a deterrent to the success of the nation. Nothing could be more remarkable than the desire to settle disputes, to withdraw pending claims, and to keep silent over ancient differences. The value, if any, of strikes was at a discount. The second point is that when a feeling arose that certain people were gaining an advantage and were obtaining out of the war results for themselves, results now known as profiteering, and were not increasing the remuneration for the employees or giving them, in spite of the increase in the cost of living, a reasonable share of the proceeds, strikes began. That was the basic cause of the Clyde strikes of February, 1915, whatever subsequent developments

may have been. The third point is that when principles of settlement, the advice of Ministers, and the advice of Labour leaders of note, and of Labour leaders of the district, well versed in the details of the dispute, were overthrown by certain Ministers in the South Wales coal strike of July, 1915, for a transitory advantage, grave encouragement was given to hostile minorities, the influence of moderate Labour leaders was seriously impaired, and Acts of Parliament could not carry their proper weight.

In spite of these matters the principle of the supreme importance of the war led to remarkable adherence to voluntary, and later to compulsory arbitration; and, on the whole, I think it may be claimed that, although there were many difficulties and hindrances, of which the famous twelve and a half per cent. was one, this compulsory machinery, unsuitable for times of peace, did service during the war. In 1913 the number of cases referred to arbitration was about 45; in 1918 the number was over 3,500; and during the five years it nearly reached 8,000, and according to the Twelfth Report under the Conciliation Act, "the awards were almost universally accepted." I draw no deductions from strikes in time of war, or from arbitration and conciliation in time of war, as to values in times of peace.

Shortly before the close of the war an epidemic of strikes and threats of strikes seemed to have set in, the most disturbing being that of the Metropolitan Police. They were gradually settled, but at the time of the Armistice there were many possibilities of claims likely to lead to strikes, of which one of the earliest came in the spinning and cardroom sections of the cotton trade. But without a strike a momentous change was made in industry, when the engineering employers and associations suddenly arranged to have a 47-hour in place of a 54-hour week. A demand had been pending before the war, but had been deferred. The concession was now given without dispute, but although it saved some trouble in one trade, the manner in which it was given produced as much consequential trouble as if the principle had been conceded in answer to a strike without attention to details. The employers concluded that the 47 hours meant 47 hours' actual work, the men that it meant something else. "Before there was an opportunity for the two sides to come together calmly to solve these differences of interpretation, notices were put up, shop meetings were held, growing into larger mass meetings, and strikes or threats of strikes." "Here we had an instance," as Mr. Clynes well remarked, "a very outstanding instance, of what at least might be called a great inadvertence, if not a very great blunder. Business men in any one trade should be careful of what they are doing, and the associations of workmen should be equally careful, because of the influence of example."

In the following two months there were strikes galore all over the country. The stirring of the war and the claim that the Government, engaged in lavish expenditure and grandiose schemes, could be made to yield, induced large numbers of men to support demands without regard to the possibilities of the future of industry. Men desired to have a share in the assumed millions, which did not appear to be used to reduce the cost of living. There was talk of a better time and more of the amenities of life without more work, often with less work, and without production even equivalent to the amount produced per head in the years previous to the war. There followed the coal strike, on the proposals for nationalization of the mines, increase of wages and shorter hours. The dispute was referred to the Sankey Commission after disastrous consequences to industry and to the progress of reconstruction. In the autumn came the Railway strike, an absolutely unnecessary strike, injurious to the railway men and to the public, and also the ironmoulders' strike. This latter strike lasted a long time and harmed the whole of the engineering industry, with very small, if any, tangible results to the moulders themselves. Of what value were these strikes? They brought in certain cases temporary gain to sections of industry, but they harmed the community as a whole. They raised prices and led to the pursuit of prices by increased wages which could not be maintained. By hindrance of production they have brought unemployment. The country is slowly engaged in undoing many of the temporary expedients then tried. It was a period of innovation without any orderly development. Some of the changes, particularly of hours, may be maintained, but it will take some time to build up the intervening conditions which

would make those changes stable and based upon a sure foundation.

Generally speaking, I would say that very few deductions in favour of the value of strikes can be drawn from this period or the temporary period of exhaustion now shadowing industry. They aided, if anything, in the prevention of that growth which was open to the country at the close of the war.

On the other hand, there were negative results in principle which may have far-reaching effects on the judgment of men. These strikes have led to an extreme distaste in the minds of very many people against nationalization of industries. They have caused the interference of Government to be regarded with suspicion by almost all classes and with active opposition by some classes. They have aided in the exposure of the useless waste of power incurred in the frequent use of sympathetic strikes, strikes which summon men for no dispute of their own to leave work, endure hardship and lose opportunities of success. They have shown up the futility of direct action and the very strong dislike which the community evinces to any dictation by one section of men or one class of men. These I should call negative results which may or may not impress men.

Through the kind assistance of Mr. Hilton, of the Intelligence and Statistics Department of the Ministry of Labour, I am able to append to this address a statement of the principal post-war strikes, and the numbers engaged in them, with a brief statement of results, but will not weary you by reading them. The statement may be examined by any Fellow in the *Journal*.

For the lessening of such disputes and their effect upon the future of this country, I do not advocate legislation or compulsory arbitration. These remedies which are sometimes suggested cannot meet the difficulty. It should be met by the spirit of the people, by realizing the danger which arises from disputes, many of which can, and should be, avoided, by education both of leaders amongst employers and employed, and particularly of the masses of employed. It is no upward road leading to any millennium which is being followed by this form of civil war, but a disintegration of which the effect is not, I think, sufficiently realised.

To take only one trade as an example, the important and vital trade of engineering, have they gained by the millions spent by their societies and the losses to firms and to the country through strikes and lock-outs? In 1889 they received about 35/- per week, and now with the cost of living higher by (say) 100%, they would receive about 57/- per week, after 33 years adherence to a policy of disputes in preference to efforts for the success of the business in which they are engaged.

Will you permit me to bring to your notice, though with some regret, because figures are dull to listen to, a few statistics? The figures, if studied, may call the attention of those who cause or take part in strikes to an estimate whether the game is worth the candle, whether they gain or lose more upon the balance. In reported strikes, excluding disputes affecting less than ten workpeople, there have been directly engaged, from 1893 to August, 1922, 14,702,000 work people. This figure must be increased by 2,831,000 workpeople thrown out of work at the establishments where the disputes occurred though not themselves parties to the disputes, and in addition there must be taken into account the unknown numbers thrown out of work at other establishments, or in industries other than those in which the disputes occurred. In this period there have been lost 381,817,000 working days. Out of these grand totals in the three years, 1911 to 1913 before the war (omitting 1914 as half in and half out), 1,580,000 persons, or 10½%, were directly and 534,000 indirectly engaged in strikes, and 62,866,000 working days were lost. As the number is swelled by the coal strike of 1912, a more normal period might be 1908-1910. In that period, 779,000 persons, or 5%, were directly and 330,000 indirectly engaged in strikes, and 23,503,000 working days were lost. We may then take three full years during the war, 1915, 1916 and 1917. In those years, 1,266,000 persons, or 8½%, were directly and 393,000 indirectly engaged in strikes, and 11,430,000 working days were lost. Compare these periods with three full years since the war, 1919, 1920 and 1921. In those years, approximately 5,990,000 persons, or 40½%, were directly and 316,000 indirectly engaged in strikes, and 148,014,000, or nearly 39%, working days were lost. Another comparison may be made. Out of 14,702,000 persons engaged in strikes during 29½ years, from 1893 to August, 1922, 5,990,000 were engaged in them during the

three years 1919, 1920 and 1921, and out of 381,817,000 working days lost in those 29½ years 148,014,000 were lost in three years, at a time when the world was poor, and when every effort to repair damage was necessary, at a time when obligations and debts have to be met and when the estimated gross expenditure on public services alone amounts for 1922-3 to £948,113,000 as against a total expended during 1913-14 of £207,817,437. Can any nation continue for a series of years to bear such a continuous restriction upon ordinary progress and upon the establishment of confidence? Without confidence, ordinary progress and reasonable chances of prosperity fade away. Uncertainty is the clog on trade, and by trade our nation lives. The figures should make every moderate man and woman pause, and though the destruction of capital, by whomsoever held, may gladden the hearts of theorists who have invented no scheme to replace it, the vast majority of people in this country at least must surely desire peace.

APPENDIX.

DETAILS OF EXCEPTIONALLY LARGE DISPUTES OCCURRING SINCE THE END OF THE WAR.

Occupations (a) and Locality.	Approximate Number of Workpeople involved.		Date when dispute		Cause or object (a)	Result (a)
	Directly.	Indirectly (a)	Began.	Ended.		
Coal miners, &c., Yorkshire.	150,000 (b)	—	1919. 9th Jan.	1919. 23rd Jan.	For simultaneous stoppage of 20 minutes per shift for surface workers' meal and demand for other concessions.	Demand for simultaneous stoppage of 20 minutes granted for period of Government control; other questions affecting surface workers promised early consideration.
Coal Miners, &c., Wales, Midland Co.'s, Yorks, &c.	100,000	—	24th March	29th March	In support of miners' national demand for advance in wages reduction in working hours, nationalisation of mines, &c.	Work resumed pending result of miners' national ballot vote upon the terms offered by the Government.
Coal miners, enginemen, stokers, pumpmen, mechanics, &c., Yorks.	150,000 (c)	—	16th July.	20th Aug.	For advance of 14.3 per cent. in piece rates to compensate for reduced working hours under Sankey Awards, and for other concessions as to working hours of underground and surface workers.	Men accepted national agreement as to piece rate resulting in an advance of 12.2 per cent. in piece rates of underground workers; other points arranged or to be discussed after resumption of work in accordance with employers' terms.
Ironfounders, coremakers and dressers, foundry labourers, &c.—England, Wales and Ireland.	45,000	20,000	22nd Sept.	1920. 24th Jan.	For advance in wages of 15s. per week to journeymen and 7s. 6d. per week to apprentices with equivalent increases in piece and lieu rates.	Wages of males over 18 years of age to be advanced 5s. per week, provision to be made for the prevention of disputes, and a conference to be held to discuss working conditions.
Cotton spinners, piecers, card & blowing room operatives, &c.—Lancashire and adjoining Counties.	450,000	—	23rd June.	1919. 12th July.	For advance of 30 per cent. on standard list rates of wages and reduction in working hours from 55½ to 46¼ per week.	Advance of 30 per cent. and 48-hour working week granted, the altered rates of wages to remain unchanged until 30th April, 1920.

NOTE.—For Explanatory Footnotes, see end of Statement.

Occupations (a) and Locality.	Approximate Number of Workpeople involved. Directly.	Indirectly. (a)	Date when dispute Began.	Ended.	Cause or object (a)	Result (a)
Railway workers —Great Britain.	500,000		27th Sept.	5th Oct.	Dissatisfaction with Government proposals for standardising rates of wages of railway workers other than engine drivers, firemen and cleaners, whereby an average advance of 100 per cent. over pre-war rates was granted subject to a minimum of £2 per week and a guarantee that no reduction in wages should take place until the cost of living had fallen below 110 per cent. above pre-war level and had remained below for at least three months.	Negotiations for standard rates of wages to continue; present wages stabilised until 30th September, 1920; minimum wage of 51s. per week guaranteed to adult railwaymen while the cost of living is not less than 110 per cent. above pre-war level.
Coal Miners, &c. — Great Britain.	1,100,000		1920. 18th Oct (e)	1920. 3rd Nov.	For advance in wages (not conditional upon output) of 2s. per shift for persons of 18 years of age and upwards, 1s. per shift for persons under 18, and 9d. per shift for persons under 16. (The Government offered an advance conditional upon output, but the conditions were not accepted by the miners.)	Advance granted temporarily, subject to adjustment under a sliding scale arrangement whereby both miners' wages and owners' profits rose and fell with the total value of export coal (calculated upon output basis). A permanent scheme for the regulation of wages in the industry was to be submitted to the Government not later than 31st March, 1921, but before such a scheme was drawn up, Government control of the industry was withdrawn.
Shipyard joiners and carpenters *and other shipyard workers.*— Great Britain.	25,000 (f)		1st Dec.	1921. 22nd Aug. (g)	Against proposed withdrawal of special advance in wages of 12s. per week granted in April, 1920.	Of the special advance, 6s. per week to be withdrawn immediately, and 3s. per week to be withdrawn as from 1st October, the remaining 3s. per week to be subject of negotiations in December.
Cotton spinners, piecers & creelers, *cardroom operatives, &c.* — Oldham & District.	20,000 (h)	20,000 (h)	15th Sept. (h)	1920 (i). 18th Oct.	Refusal to accept the terms of an agreement signed by representatives of employers and workpeople providing for the partial withdrawal of extra payments made under a war-time arrangement whereby female creelers were employed in the absence of "little piecers" (male).	Work gradually resumed on terms of the agreement.

NOTE.—For Explanatory Footnotes, see end of Statement.

Occupations (a) and Locality.	Approximate Number of Workpeople involved. Directly.	Indirectly. (a)	Date when dispute Began.	Ended.	Cause or object (a)	Result (a)
Coal miners, &c.—Great Britain.	1,150,000 (k)	—	1921. 1st April.	1921. 1st July.	Dispute arising out of dissatisfaction with district rates of wages proposed by the employers, following the withdrawal of Government control of the industry.	Agreement arrived at providing, *inter alia*, for the periodical adjustment of wages on the basis of the proceeds of the industry in each of thirteen districts, subject to a minimum wage 20 per cent. above the pre-war level, and to the maintenance of a subsistence wage for low paid day workers and the granting of a temporary Government subsidy in aid of wages.
Workpeople in the cotton spinning and manufacturing industry.—Lancashire, Cheshire and adjoining Counties.	375,000 (l)		6th June.	24th June.	Against proposed reduction of 80 per cent. from standard piece price list rates of wages, workpeople offering a reduction of 50 per cent.	Agreement effected providing for immediate reduction of 60 per cent. from list rates (equivalent to a reduction of about 19 per cent. from prevailing actual rates of wages), a further reduction of 10 per cent. from list rates to take place in December.
Engineers, etc., in the employment of firms affiliated to the Engineering and the National Employers' Federations, United Kingdom. (1) Members of the Amalgamated Engineering Union. (2) Members of other Trade Unions.	250,000 (m)	10,000	1922. (1) 13 March. (2) 3 May	1922. (1) 13 June (2) 2 June (n)	Lock-out consequent upon workpeople's refusal to agree that employers' instructions as regards changes in workshop conditions shall be observed pending the discussion in accordance with the procedure for avoiding disputes of any question in connection therewith. In the case of the Amalgamated Engineering Union the right of the employers to decide when overtime on production work is necessary (within the limit of 30 hours in any four weeks) was also contested.	Employers' proposals accepted, subject to provision for the discussion in an establishment, prior to managerial decision, of such changes as would result in the replacement of one class of workpeople by another. Where a class of workpeople is displaced, consideration to be given to the case of workpeople so displaced with the view if practicable, of affording them in the establishment work suitable to their qualifications.
Shipyard Workers—Federated Districts and certain other Districts (o).	90,000 (p)		29th March	6th May (q)	Against proposed reduction of war bonus by 10s. 6d. a week from 29th March, with a further reduction of 6s. on 26th April.	Reductions accepted of 10s. 6d. a week as from 29th March, followed by 3s. on 17th May, and 3s. on 7th June.

EXPLANATORY NOTES.

(*a*) The occupations underlined are those of workpeople "indirectly involved," *i.e.*, thrown out of work at the establishments where the disputes occurred, but not themselves parties to the disputes. The statements of cause and result do not apply to these persons.
(*b*) Estimated. The great majority of these workpeople were on strike for one or two days only.
(*c*) In addition a large number of workpeople were rendered idle in the metal, textile, etc., trades.
(*d*) The dispute terminated on the 15th August, in South Yorkshire, but continued until 20th August in West Yorkshire.

(e) The general strike on 18th October, was preceded by partial stoppages in South Wales, Lanarkshire and other Districts during the first week in October, arising out of dissatisfaction with the progress of the national negotiations. These local stoppages lasted from one to three days, and are estimated to have involved about 50,000 workpeople.
(f) Estimated average. The actual numbers varied at different dates during the dispute. The maximum number directly involved was about 10,000.
(g) In certain districts the workpeople remained out for a few days after this date.
(h) The number of workpeople on strike reached its maximum about 22nd September.
(i) The majority of the workpeople resumed work on 5th October.
(k) Estimated number of workpeople originally involved in the dispute (somewhat reduced in the course of the dispute by the return to work of a number of pumpmen, etc).
(l) Estimated number, exclusive of workpeople who were unemployed when the stoppage began.
(m) Estimated number involved, exclusive of workpeople unemployed when the stoppage began. Exact figures are not available.
(n) In the case of the National Union of Foundry Workers, a settlement was reached on 13th June, and in the case of the United Society of Boilermakers, on 20th June.
(o) The districts involved included the Clyde, East of Scotland, North-East Coast, Hull, Barrow, Mersey, London, Southampton and Portsmouth (private firms).
(p) Estimated number involved exclusive of workpeople unemployed when the stoppage began. Exact figures are not available.
(q) Date of acceptance of terms of settlement for shipyards controlled by the Shipbuilding Employers' Federation. With ship repairing employers on the Mersey, a settlement was not effected until early in June, and on the Thames until late in July.

The CHAIRMAN then presented the medals for Papers and Lectures given during the last session as follows :—

Papers read at the Ordinary Meetings :—

PROFESSOR JOHN AMBROSE FLEMING, M.A., D.Sc., F.R.S., for the Trueman Wood Lecture, "The Coming of Age of Long Distance Wireless Telegraphy."

HOWARD MAURICE EDMUNDS, "Photo-Sculpture."

EDWARD VICTOR EVANS, O.B.E., F.I.C., Chief Chemist, South Metropolitan Gas Company, "Some Solved and Unsolved Problems in Gas Works Chemistry."

W. A. APPLETON, C.B.E., Secretary to the General Federation of Trade Unions, "The Proper Functions of Trade Unions."

JOHN FRANCIS CROWLEY, D.Sc., B.A., M.I.E.E., "The Use and Advantages of Electric Power in the Factory, as illustrated by its Application to the Jute Industry."

LAWRENCE HAWARD, M.A., Curator of the City Art Gallery, Manchester, "The Problem of Provincial Galleries and Art Museums, with special reference to Manchester."

Papers read in the Indian Section :—

PROFESSOR SIR THOMAS WALKER ARNOLD, C.I.E., Litt.D., M.A., for the Sir George Birdwood Memorial Lecture, "Hindu Painting and Muhammadan Culture."

PROFESSOR HENRY E. ARMSTRONG, Ph.D., LL.D., D.Sc., F.R.S., "The Indigo Situation in India."

Paper read in the Dominions and Colonies Sections :—

FREDERICK COATE WADE, B.A., K.C., Agent-General for British Columbia, "British Columbia—The Awakening of the Pacific."

Papers read at Joint Meetings of the Indian and Dominions and Colonies Sections :—

PROFESSOR WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., "Lignites and Brown Coals and their Importance to the Empire."

PROFESSOR W. ECCLES, D.Sc., F.R.S., M.I.E.E., "Imperial Wireless Communication."

DISCUSSION.

MR. ALAN A. CAMPBELL SWINTON, F.R.S. (late Chairman of the Council), in proposing a very hearty vote of thanks to Lord Askwith for his most masterly lecture, said no man other than Lord Askwith could have given such an address, because the subject of strikes and lock-outs was one to which his Lordship had devoted a very large portion of his life. All employers of labour were cognisant of the difficulty of arriving at what was justice in regard to wages and matters of that kind. They were also very much impressed with the fact that the amount of loss to the nation at large, owing to strikes, was enormous compared with the gains which the working man obtained by them. It should surely be possible to arrive at some means whereby disputes could be settled without strikes or lock-outs and the consequent loss entailed by the immense amount of time wasted thereby. The working man did not really like being idle, and if arrangements could be made—he himself was not competent to suggest any method—whereby disputes could be settled on some other basis, an enormous amount of good would be done.

MR. W. A. APPLETON, C.B.E. (Secretary of the General Federation of Trade Unions), in seconding the vote of thanks, said nothing could give him more pleasure than to listen to a lecture such as the one just delivered, and then to have the opportunity of himself expressing his own thanks, and he was sure the thanks of the audience, to the lecturer for what he had said. He had known Lord Askwith for a long time. He had seen his work, and he could

say that it had been characterised by understanding, by sympathy, and by infinite patience. It was not easy, when there were fools on both sides, to bear with them gladly, but he had seen Lord Askwith do that. He remembered on one occasion that Lord Askwith had kept the parties sitting for 22 hours at one stretch. On that particular occasion Lord Askwith had given the two sides every opportunity of arguing the points, and they did so until they were thoroughly tired out by the process. He believed they did eventually come to some formal agreement, either in the early hours of the morning or in the late hours of the night. That was one example of Lord Askwith's wonderful patience.

He was sure that Lord Askwith would not desire that anybody should go away with the idea that it was the workmen who were solely responsible for strikes. His own experience suggested that it was about "fifty-fifty," as the Americans said, and that the employers were more to be blamed for stupidities, because they had so many better opportunities of learning how not to be stupid. He supposed they would argue, if they had to argue that night, that the percentage of feeble-mindedness was greater among the workmen than it was among the employers, but if one were to judge from one's experience of industrial disputes, again he felt it was something like "fifty-fifty." If employers had looked ahead and had anticipated things; if they had shown consideration, and if they had been interested in the men (who were interested in their business sometimes), there would not have been half the trouble which there had been during the last few years.

He thought a differentiation ought to be made between a strike with an economic objective and a strike with a poitical objective. It was the strike with a political objective that had nearly brought this country to ruin and which had almost sacrificed the Trade Union movement, which to-day found itself in a very serious positon. It would take the whole of the wisdom of all its best leaders to bring it out of the wilderness into which the politicians had led it.

He was very pleased indeed to hear that Lord Askwith was not in favour of compulsory arbitration, or anything in the shape of legislation, to force men to accept economic decisions. His friend, Mr. Archie Crawford, the Secretary of the South African Federation of Trade Unions, was present, and they had been discussing the subject that very afternoon, and they had agreed that in the event of compulsion being adopted it would be those who applied compulsion as well as those who were brought under it who would suffer. It was very striking to consider that three men like Lord Askwith, Mr. Crawford and himself, all working in different spheres, but dealing with similar situations, had come to the same conclusions about the matter of compulsion.

While agreeing that some strikes were of little economic value, they did have what he might call an evaporative value—they did permit the letting off of steam occasionally. They also had an educative value. He doubted very much whether it would have been possible for the most eloquent amongst the leaders to have persuaded the men that a strike for political purposes was bound to result in failure, if those leaders had not had the experiences of the last few months. It had to be remembered that each generation must learn by its own experiences, because no generation was sufficiently wise to learn by reason.

He was very pleased indeed to second the vote of thanks, and to feel that there was so much interest now being taken in so profoundly important and interesting a subject.

THE CHAIRMAN briefly acknowledged the vote of thanks, and the proceedings terminated.

GENERAL NOTES.

DEVELOPMENT OF HYDRO-ELECTRIC POWER IN FRANCE.—A measure authorising the construction of systems for the transmission of high tension electric energy in France has passed the Chamber of Deputies and been adopted by the Senate. The Bill aims at providing for irregularities in power of central stations due to shortage in water supply at various seasons, etc. A law of 11th August, 1920, granted permission for the construction of such connecting systems for transmission of energy in the liberated provinces, and the work will be finally completed in 1923. After 1937 nine million tons of fuel will be economised annually as the outcome of the present schemes. As a result of a saving of two milliards a year on coal now imported into France from abroad, it is calculated that the expenditure on constructing the stations and systems will be recovered in six years.

RESEARCH FOR METALS INDUSTRY.—A pamphlet entitled "Research Work in Progress," has just been issued by the British Non-Ferrous Metals Research Association of 71, Temple Row, Birmingham. The investigations in hand cover many important problems of the Copper, Brass, Aluminium, Nickel and Lead Industries, as well as subjects of importance to all users of such metals. The support given to this Association by the leading firms seems to be encouraging, but the field covered is very wide and many of these researches, such as those on the improvement of brass, on metal polishing, and on soldering should attract the attention and support of many other sections of industry. Some indication is given of the further work which the Council hope to take up when additional financial support is forthcoming, which includes problems of importance to the Electrical Industries, to Die Casters and to the Tin Plate Trade.

INDIAN WOOLLEN INDUSTRY.—There is every probability of Indian-made woollen goods entering into keen competition with British-made goods in the near future, states *The Calcutta Commercial Gazette*. The producers of Bradford and Huddersfield could not meet the requirements of India during the war period, with the result that mills that happened to be in North India did an excellent business and paid good dividends. Travelling rugs, blankets and cloths were made from East Indian wool and also from raw material supplies from Australia and New Zealand. In 1920 four big companies were projected, all in Bombay, but on account of the difficulty of getting machinery, one of them closed down. Better success awaited another one, and it is now producing fine fabrics. The mill has eleven worsted and six woollen sets. The third mill has eight worsted and six woollen sets, and work is about to begin shortly. While Bradford has to pay freight on the raw material, and also on the finished fabric sent out to the East, the Indian mills have only the freight on the Australian wool to bear.

MEETINGS OF THE SOCIETY.

ORDINARY MEETINGS.

Wednesday evenings, at 8 o'clock:—

NOVEMBER 29.—MAJOR W. S. TUCKER, R.E., D.Sc., "The Hot Wire Microphone and its Applications to the Problems of Sound." Admiral of the Fleet SIR HENRY B. JACKSON, G.C.B., K.C.V.O., D.Sc., F.R.S., will preside.

DECEMBER 6.—H. EMORY CHUBB, "Recent Developments in the Manufacture of Safes and Strong Rooms." (With Cinematograph illustrations.) LAURENCE CURRIE will preside.

DECEMBER 13.—SIR SIDNEY F. HARMER, K.B.E., Sc.D., F.R.S., Director of the British Museum of Natural History, "The Fading of Museum Specimens." THE EARL OF CRAWFORD AND BALCARRES, K.T., P.C., F.S.A., will preside.

INDIAN SECTION.

Friday afternoon, at 4.30 o'clock.

DECEMBER 15.—Commissioner F. de L. BOOTH TUCKER, "The Settlements of Criminal Tribes in India." SIR EDWARD R. HENRY, Bt., G.C.V.O., K.C.B., Inspector-General of Police, Bengal, 1891; Commissioner of Police in the Metropolis, 1903-18, will preside.

DOMINIONS AND COLONIES SECTION.

Tuesday afternoon, at 4.30 o'clock.

DECEMBER 5.—MAJOR OWEN RUTTER, F.R.G.S., F.R.A.I., "North Borneo" (with Cinematograph Views).

PAPERS TO BE READ AFTER CHRISTMAS.

THOMAS H. FAIRBROTHER, M.Sc., F.I.C., and ARNOLD RENSHAW, M.D., D.P.H., "The relation between Chemical Constitution and Antiseptic Action in the Coal Tar Dyes."

CHARLES R. DARLING, A.R.C.Sc.I., "Electrical Resistance Furnaces and their Uses."

WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Recent Developments in Surface Combustion."

W. J. REES, Lecturer on Refractories in the University of Sheffield, "Progress in the Manufacture of Refractories."

ARTHUR W. REEVES, M.I.Mech.E., M.Inst. Auto. Eng., "Motor Railway Coaches."

MAURICE DRAKE, "The Development of Mediæval Technique in Stained Glass Windows."

EDWARD PARNELL, "The Resources and Trade of Sarawak."

C. AINSWORTH MITCHELL, M.A., F.I.C., "Handwriting and its value as Evidence."

PROFESSOR W. E. S. TURNER, D.Sc., Head of Department of Glass Technology, The University, Sheffield, "Heat Resisting Glasses."

THE EARL OF RONALDSHAY, G.C.I.E., late Governor of Bengal, "A Clash of Ideals as a Cause of Indian Unrest."

J. T. MARTEN, I.C.S., M.A., Imperial Census Commissioner in India, "The Indian Census, 1921."

SIR RICHARD A. S. REDMAYNE, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S., "The Base Metal Resources of the British Empire."

L. GUY RADCLIFFE, M.Sc. (Tech.), F.I.C., "The Essential Oils of the British Empire."

BRIGADIER-GENERAL H. A. YOUNG, C.I.E., C.B.E., "The Indian Ordnance Factories."

R. W. CHURCH, B.Sc., F.G.S., "Electrification of Indian Coalfields."

LIEUT.-COLONEL SIR LEONARD ROGERS, C.I.E., F.R.S., F.R.C.P., F.R.C.S., Physician and Lecturer, London School of Tropical Medicine, "Recent Advances towards the Solution of the Leprosy Problem."

INDIAN SECTION.

Friday afternoons, at 4.30 o'clock.

January 10, February 16, March 16 April 20, May 11.

DOMINIONS AND COLONIES SECTIO .

Tuesday afternoons, at 4.30 o'clock.

February 6, March 6, May 1.

CANTOR LECTURES.

Mon a evenings, at 8 o'clock.

WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor o Chemical Technology, Imperial College of Science and Technology, South Kensington, "Brown Coal and Lignites." Three Lectures. November 27, December 4 and 11.

SYLLABUS.

LECTURE I.—Brown Coals and Lignites. Their Origin and Classification. Geographical Distribution. Physical Texture and Ultimate Chemical Composition. Their importance to the British Empire.

LECTURE II.—Some factors governing the Commercial Utilisation of Brown Coals and Lignites. The drying and briquetting of them. Process of preliminary Heat Treatment as a means of improving their Fuel Values.

LECTURE III.- The Carbonisation of Brown Coals and Lignites and By-Products therefrom. Their employment as steam raising fuels.

HENRY P. STEVENS, M.A., Ph.D., F.I.C., "The Vulcanisation of Rubber." Three Lectures. February , 12, 19.

J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards, "Length Measurement." Three Lectures. March 5, 12, 19.

SAMUEL A. DAVIES, Chemical Department, Messrs. Rowntree & Co., York, "Cocoa and Chocolate." Three lectures. April 9, 16, 23.

HOWARD LECTURES.

Monday evenings, at 8 o'clock.

STANLEY S. COOK, "Recent Improvement in Steam Turbines." Three Lectures. April 30, May 7, 14.

DR. MANN JUVENILE LECTURES.

Wednesday afternoons, at 3 o'clock.

CHARLES R. DARLING, A.R.C.Sc.I., F.I.C., "The Spectrum, its Colours, Lines, and Invisible Parts, and Some of its Industrial Applications." Two Lectures. January 3 and 10, 1923.

MEETINGS OF OTHER SOCIETIES FOR THE ENSUING WEEK.

MONDAY, NOVEMBER 27 .. Geographical Society, 135, New Bond Street, W., 8.30 p.m.

TUESDAY, NOVEMBER 28 .. Royal Dublin Society, Leinster House, Dublin, 4.15 p.m. 1. Prof. J. Wilson, "On the Variation in Milk Yield with the age of the Cow and the length of the Lactation Period." 2. Mr. H. H. Poole, "The Detonating Action of α Particles." 3. Mr. T. G. Mason, "A Note on Growth and the Transport of Organic substances in Bitter Cassava (Manihot Utilissima)."

Colonial Institute, Hotel Victoria, Northumberland Avenue, W.C., 4 p.m. Sir Alfred Pickford "The Boy Scout Movement; What it is and especially What it is Not."

Oriental Studies, School of, Finsbury Circus, E.C., 5 p.m. Sheikh M. H. Abdel Razek, "The Study of Moslem Civilisation in Europe."

Labour Co-Partnership Association, at the Women's Engineering Society, 26, George Street, Hanover Square, W., 5 p.m. Miss C. S. Bremner, "Co-partnership at Guise."

WEDNESDAY, NOVEMBER 29 .. University of London, University College, Gower Street, W.C., 6.15 p.m. Mr. A. W. Flux, "The Foreign Exchange." (Lecture 4.) "Inflation and Deflation."

British Academy, at the Royal Society, Burlington House Piccadilly, W., 5 p.m. Prof. J. Ward, "Immanuel Kant."

United Service Institution, Whitehall, S.W. 3 p.m. Lt.-Gen. Sir Aylmer Haldane, "The Arab Rising in Mesopotamia, 1920."

Industrial League and Council, Caxton Hall, Westminster, S.W., 7.30 p.m. Mr. J. E. Barker, "Britain's Industrial Problems."

Public Health, Royal Institute of, 37, Russell Square, W.C., 4 p.m. Mr. C. E. Wallis, "School Dental Clinics."

THURSDAY, NOVEMBER 30 .. University of London, at the London School of Economics, Houghton Street, W.C. Sir Frederick Lugard, "Economic and Administrative Problems of the British Tropics." (Lecture II.)

Optical Society, Imperial College of Science and Technology, Imperial Institute Road, S.W., 7.30 p.m. Discussion on "Spectacles and Spectacle Construction."

Child Study Society, 90, Buckingham Palace Road, S.W., 6 p.m. Dr. A. F. Tredgold, "Some Problems relating to Mental Deficiency."

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C., 6 p.m., Mr. W. A. Gillott, "Domestic Load Building; A few Suggestions upon Propaganda Work."

Linnean Society, Burlington House, Piccadilly, W., 5 p.m.

Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.

Camera Club, 17, John Street, Adelphi, W.C., 8.15 p.m. Dr. C. Atkin Swan, "Bicennitz Carcassonne."

FRIDAY, DECEMBER 1 .. Mechanical Engineers, Institution of, Storey's Gate, S.W., 6 p.m. Dr. T. E. Stanton, "Some Recent Researches on Lubrication."

SATURDAY, DECEMBER 2 . St. Paul's Ecclesiological Society, at the Church of St. Mary Aldermary, Queen Victoria Street, E.C., 3 p.m. Mr. A. May, "Elizabethan Motets."

Announcements intended for insertion in this list must be received at the SOCIETY'S Office not later than the Monday of the week preceding the Meeting.

*For Meetings of the ROYAL SOCIETY OF ARTS, see page 1.

Journal of the Royal Society of Arts.

No. 3,654. VOL. LXXI.

FRIDAY, DECEMBER 1, 1922.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

NOTICES.

NEXT WEEK.

MONDAY, DECEMBER 4th, at 8 p.m. (Cantor Lecture.) WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Brown Coal and Lignites." (Lecture II.)

TUESDAY, DECEMBER 5th, at 4.30 p.m. (Dominions and Colonies Section.) MAJOR OWEN RUTTER, F.R.G.S., F.R.A.I., "North Borneo" (with Cinematograph Views). EDWARD DENT, M.A., Vice-President, Court of Directors, British North Borneo Company, will preside.

WEDNESDAY, DECEMBER 6th, at 8 p.m. (Ordinary Meeting.) H. EMORY CHUBB, "Recent Developments in the Manufacture of Safes and Strong Rooms." (With Cinematograph Views.) LAURENCE CURRIE will preside.

THIRD ORDINARY MEETING.

WEDNESDAY, NOVEMBER 22nd, 1922; THE RIGHT HON. LORD NEWTON, P.C., in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Burns, Robert, Houghton, Co. Durham.
Horton, George Craigen, Liverpool.
Jana, Dr. Ashutosh, M.Sc., LL.B., Bengal, India.
McNish, Colonel George, C.B.E., Glasgow.
Maxwell, Marshall Andrews, B.Sc., Huntingdon, West Virginia, U.S.A.
Puech, Lieut-Colonel A. G., O.B.E., V.D., Delhi, India.
Traphagen, Frank W., Ph.D., Los Angeles, California, U.S.A.
Trollope, Clifford Cecil, London.

The candidates proposed at the Opening Meeting on November 8th, of whom a list was published in the *Journal* of November 17th (pages 871-873) were duly elected Fellows of the Society.

A paper on "The Economy of Smoke Abatement" was read by Ex-Bailie William B. Smith (Glasgow), Member of the Departmental Committee on Smoke Abatement.

The paper and discussion will be published in the *Journal* of December 22nd.

MANN JUVENILE LECTURES.

Under the Mann Trust a short course of lectures adapted to a juvenile audience will be delivered on Wednesday afternoons, 3rd and 10th January, 1923, at 3 p.m., by Mr. Charles R. Darling, A.R.S.Sc.I., F.I.C., on "The Spectrum, its Colours, Lines, and Invisible Parts, and some of its Industrial Applications." The lectures will be illustrated with experiments.

Special tickets are required for these lectures. A sufficient number to fill the room will be issued to Fellows in the order in which applications are received, and the issue will then be discontinued. Subject to these conditions, each Fellow is entitled to a ticket admitting two children and one adult. Fellows who desire tickets are requested to apply to the Secretary at once.

LIST OF FELLOWS.

The new edition of the List of Fellows of the Society is now ready, and copies can be obtained on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.

SPECIAL MEETING.

MONDAY, NOVEMBER 13TH, 1922.

LORD ASKWITH, K.C.B., K.C., D.C.L., in the chair.

THE STRAND AND THE ADELPHI: THEIR EARLY HISTORY AND DEVELOPMENT.

By JOHN SLATER, F.R.I.B.A.

It seems only fitting that the first ordinary meeting of this Society since it has purchased the freehold of the building in which we are now assembled should be devoted to

a short historical account of the site and its surroundings. I feel, however, this evening that I am standing in someone else's shoes and that this paper should have been read by Sir Henry Trueman Wood, the indefatigable secretary of the Society for so many years, who has written its history. Unfortunately, he has not felt able to undertake the task, and the duty has devolved on me, and I cannot but feel much honoured in being associated with such an interesting historic occasion.

It is not my intention to-night to give you any résumé of the multifold activities of this old Society during the last hundred-and-sixty years or more; you can read the account of these in Sir Henry's book. It is the topographical interest of the site and its surroundings and the vast changes that have come over them that I shall endeavour to bring before you.

The topographical history of this great city of London can only be dealt with piecemeal. London is an agglomeration of many individual units and the more one studies these units, each with its own separate idiosyncracies, and traces their growth and development and final absorption into the huge London that we now know, the deeper and wider becomes our interest. I said "the London that we know," but do we really know it? I venture to think that not one man in a thousand who walks the streets of this city has the slightest idea of the features of the old London or of the vast changes that have occurred in comparatively few years. A hundred years ago people used to go from London for country air to the villages of Marylebone and Bayswater, and footpads used to haunt the roadways leading to these places. Then take the configuration of the ground: this is now completely disguised, although an observant eye—especially at night time when the street lamps are lit—may, by watching their rise and fall, get some notion of the inequalities of surface. A gentle dip followed by a rise almost always indicates the points where the numerous old water-courses originally ran. This is particularly noticeable in Wigmore Street, Oxford Street just east of Selfridges and in Piccadilly close to Half Moon Street; all these points mark the course of the old Ty-bourne. At Knightsbridge, close to Sloane Street, the course of the Westbourne is indicated, at the east end of Fleet Street the course of the old Fleet River and close to the Bank, that of the Walbrook are marked. In order to give you some idea of the configuration of the ground before London was built, I have made a rough map shewing the various streams which ran down to the Thames from the high ground on the north and south. You will notice the Holebourne which ran down Faringdon Street at the bottom of Snow Hill, now obliterated by the Holborn Viaduct, and joined the Fleet River, up which barges could sail for a considerable distance; the Tybourne, the Westbourne and others that I have mentioned. These main streams had many small tributaries, and it is stated that between the Tower and Charing Cross there were no less than a hundred little rivulets running into the Thames with wooden bridges over them.

This evening we are only concerned with a very narrow strip of London between the city boundary at Temple Bar and Charing Cross, about half-a-mile in length and 250 yards in width from the north bank of the river up to Covent Garden, and in telling the story of this little piece my remarks will have to be much condensed to bring them within the reasonable limits of an evening lecture.

We all know the Strand (Fig. 1)—the busy thoroughfare between the City and Westminster—which Charles Lamb loved so much. Originally, as its name implies, the Strand was simply the river-bank from which the foreshore sloped down to the lapping waters of the Thames, but in old times the level of the road was much lower than now and the foreshore was very different. I can show you a portion of one of the ordnance maps on which I have indicated the old foreshore, and you can see where the various landing stairs were situated In those days the river was the great highway, and the road—so badly was it kept up—was nothing but a byway, the earliest houses that were built all having their fronts to the river, and their back-yards and stables towards the road. We have it recorded in 1315 that "the way from Temple Bar to Westminster was so bad that the feet of horses and of rich and poor alike received constant damage, particularly in rainy seasons, and the footway was interrupted by thickets and bushes." In 1353 the roadway was well-nigh impassable so deep and muddy was it—*profunda et lutosa*, as the old chronicles say. In

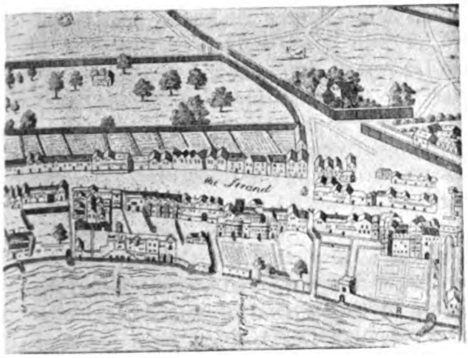

FIG. 1.—Parts of the Strand and Covent Garden, as they appeared in the Reign of Queen Elizabeth.

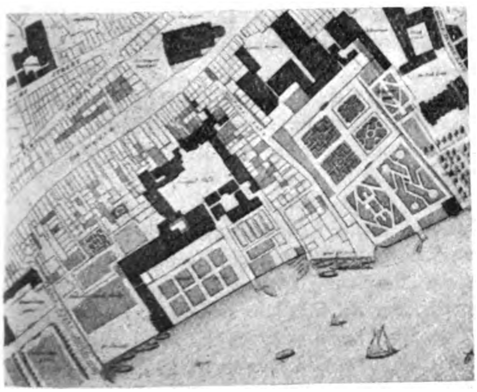

FIG. 2.—Plan of Arundel and Essex Houses.

FIG. 3.—Courtyard of Arundel House.

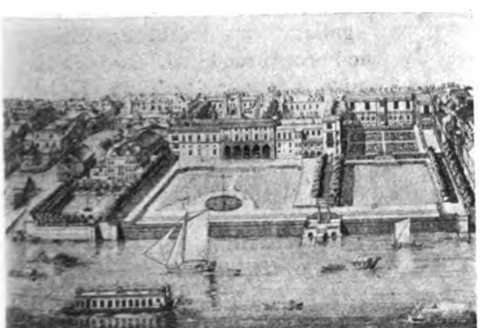

FIG. 4.—Southern Front of Somerset House, with its Gardens, etc.

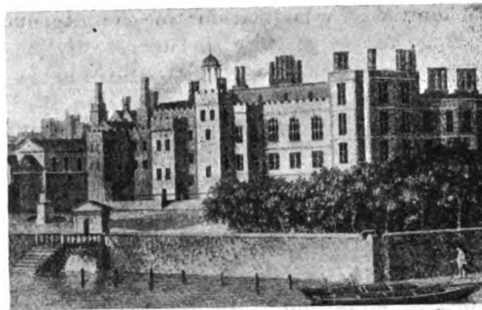

FIG. 5.—Somerset Palace.

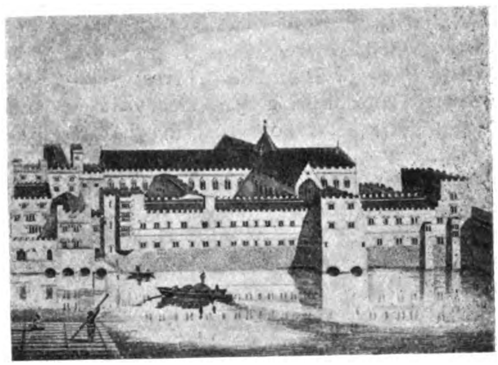

FIG. 6.—The Savoy.

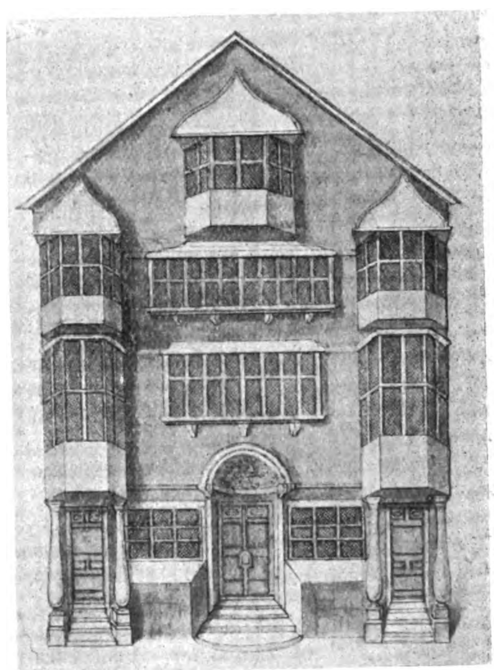

FIG. 8.—Old Timber House in the Strand, pulled down in 1725.

1532 an Act was passed "for sufficiently paving the streetway between Charing Cross and Strand Cross," and even as late as the reign of George III., the channel which ran along the middle of the road was often so deep and slippery as to be a constant danger to carriages and horses. So lonely and dangerous was the locality in early times that no one thought of living there, and it was not till the end of the 13th century that there were any dwelling-houses in the Strand. The first mention of any building of importance occurs in the reign of Henry III., who made a grant of some tenements and lands which were situated just east of where old Northumberland House stood to the Prior of Rouncivall in Navarre, and a hospital or chapel of St. Mary was founded there, but we have no record of what this building was like. In the 30th year of the same king's reign, Stow tells us that "He did grant to his Uncle Peter of Savoy all the land on the Thames which had belonged to a certain Brian de Insula without the walls of the cittie in the way or streete called The Strand, yielding yearly in the Exchequer on the Feast of St. Michael the Archangel three barbed arrows for all services." This Peter built the first Savoy Palace, of which I shall have more to say. But as late as Edward the Fifth's reign the open country came right down to the Strand from the Postern Gate, which preceded Temple Bar, as shewn in an old print of which I have a copy. This is supposed to represent the procession of Edward VI. at his coronation to Whitehall. You will see that the perspective is faulty, as the distance from Temple Bar to Westminster is much too small and Whitehall Palace is drawn largely from imagination. What the enclosure is where the small flags are shown, I am not sure, but as we know that the citizens drilled in the fields near here, I am disposed to think that this is what is indicated. Not a house is shewn on the north side of the Strand.

Originally nearly all the south side of The Strand was occupied by the Inns, as they were called, of the various Bishops. Starting westwards from Temple Bar, we first come to what was the Bishop of Exeter's house. At the Reformation this was granted to Lord Paget, who soon sold it to Dudley, Earl of Lancaster. He practically rebuilt it, and soon afterwards it became the property of the Earl of Essex. In 1613 the Elector Palatine was lodged there, and in the Calendar of State Papers there is an amusing account of the arrangements for entertaining him. Four tables were to be provided: his own was to be laid for ten covers: the second for persons of rank eighteen in number; the third was for the esquires and pages who were to be regaled on what was left over from the first table; and the fourth was for the underlings who were to be served with the remains of the second table. The Parliamentary leader Essex lived here for some time, but in 1639 half of the house was let to the Earl of Hertford. Very large gardens were attached to this house, which was pulled down in 1680, and its site is commemorated in the existing names of Essex Street and Devereux Court.

Close by were the inns of the Bishops of Chester, Llandaff and Lichfield. We have no record of what these were like, but Chester House gave its name to Chester Inn, which was at one time one of the Inns of Court.

Next to Essex House was Arundel House (Figs. 2 and 3) which was originally the Inn of the Bishops of Bath and Wells. In the reign of Edward VI. this house was granted to Thomas, Lord Seymour, who married Queen Catherine Parr, and at his execution the Earl of Arundel bought it in 1549. He died in 1580 and Lord Howard of Effingham had it for a while, but in 1607 he gave it up to King James I., who bestowed it on Thomas Howard, Earl of Arundel. He was a great collector of works of art and formed the celebrated collection of marbles from Greece and Rome. Peacham, in his "Compleat Gentleman," says that "to his liberal charges and munificence this angle of the world oweth the first sight of Greek and Roman statues, with whose admired presence he began to honour the gardens and gallery of Arundel House, and hath since continued to transplant old Greece into England." This Duke patronized Hollar, the engraver, who lived here for some years. After a time, however, these statues ceased to be properly cared for and Evelyn in his diary in 1667 says "these precious monuments are miserably neglected and scattered up and down about the garden of the house, and the corrosive air of London has seriously impaired them." On Evelyn's recommendation the Earl gave the collection to the University of Oxford, and in 1678 the house was pulled

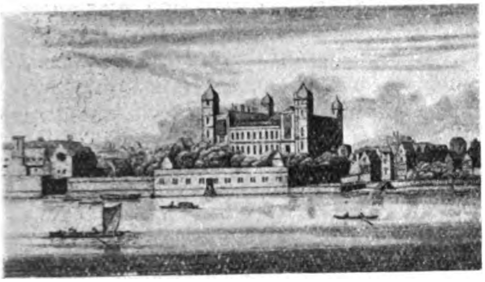

Fig. 7.—Suffolk House, Charing Cross.

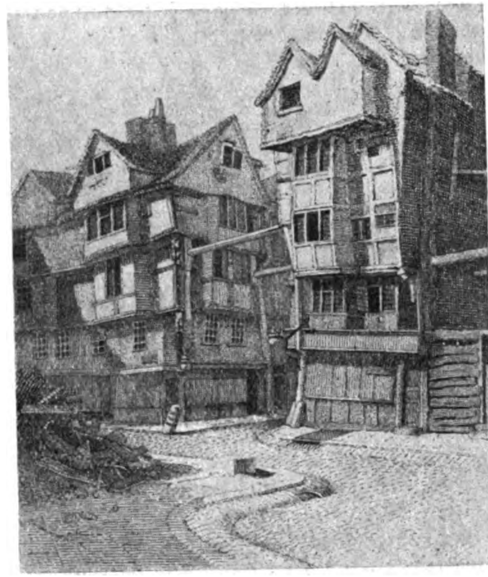

Fig. 10.—Old Houses in Butcher Row.

Fig. 9.—The Angel Hotel.

Fig. 11.—Beaumont House, Butcher Row.

Fig. 12.—Durham House, Salisbury House, and Worcester House.

down. The Royal Society for some years held its meetings here. Wren designed a large house for the site, but it was never built, and it lay derelict for some time. Gay, in his Trivia, writes:

"Where statues breathed—the work of Phidias' hands,
A wooden pump or lonely watch-house stands."

The site is now occupied by Arundel, Norfolk, Surrey and Howard Streets.

Although the majority of the streets leading out of The Strand are post Reformation, there are three of very great antiquity. They are Milford Lane, which probably commemorates the existence of an old windmill; Strand Lane, where there is still existing an old Roman bath, the water flowing uninterruptedly; and Ivy Bridge Lane. All these led down to landing stairs.

Worcester House came next: this originally belonged to the See of Carlisle, and was subsequently given by the Crown to the Earl of Bedford, but as he had a large house on the north side of The Strand, he sold this site to the Somersets.

Somerset House (Figs. 4 and 5) was built in 1549 from the designs of John of Padua on the site of the old Inns of the Bishops of Chester, Worcester and Llandaff. This site was granted by Henry VIII. to the Earl of Hertford, afterwards Duke of Somerset. Somerset was beheaded in 1552, and the property reverted to the Crown, but in 1558 it was restored to the Protector's son, Edward Seymour.

Queen Elizabeth lived here in 1570, and afterwards a portion of the house was used as a lodging for illustrious foreigners. There is a record in the Domestic State Papers that in 1596 Lady Hunsdon was appointed keeper of the Palace with a fee of twelvepence per day and sixpence a day for the garden. In 1603 Stow writes that "it is a large and most beautiful house, but yet unfinished."

On the accession of James I. it became the Court of his Queen, Anne of Denmark, for whom Inigo Jones altered it and when subsequently occupied by Henrietta Maria, Queen of Charles I, as a dower house,

"where glittering courtiers in their tissues stalked,"

it became a centre for Romanist plots and proselytising. Pepys describes the house as "mighty magnificent and costly," and having "a brave echo on the stairs." The Royal Academy was housed in old Somerset House in 1771, and after the completion of the new building, which was commenced by Sir Wm. Chambers in 1776, the Academy again had rooms here, the first exhibition of pictures in the new house being held in 1780. I show a rather interesting old print of the academicians of the time.

The next house, called Cecil and Salisbury House, was built by Sir Robert Cecil in 1602. Queen Elizabeth came to the house-warming. Ten years later the second Lord Salisbury found the house too big for him and sub-let part of it, but in 1673 it was pulled down.

The Palace of the Savoy came next (Fig. 6) This was built, as I have stated, by Peter, Duke of Savoy, when he came to England to visit his niece Eleanor, Queen of Henry III. The Duke subsequently endowed it on the Fraternity of Mountjoy of Havering in Essex, but after his death Queen Eleanor bought it back and gave it to her son, the Earl of Lancaster, in the first year of Edward I. In 1357, John, King of France, was lodged in this Palace as a prisoner, and Froissart says, "Thyder came to see him the Kyng and the queene oftentimes and made him greate feaste and cheere." He died in 1363. In 1381 the mansion was burnt down by the rebels under Wat Tyler. It was repaired in 1394, and the records say that seven labourers were paid 9s. per perch for building the wall between the Savoy and the Inn belonging to the Bishop of Carlisle. Stow says of the Great Hall that "the ceiling is very curiously built with wood having knobs in divers places hanging down and images of angels holding before their breasts coats of arms, etc." In 1509 Henry VII. enlarged and repaired the buildings and endowed them as a hospital to maintain 100 beds for poor people and keep them in food and drink under a Master and Chaplains. This King died while the work was in progress, and it was completed by his executors with the concurrence of Henry VIII., but the statutes relating to the relief of the poor soon became neglected and gross abuses crept in, so that in Queen Anne's reign the hospital was dissolved and reverted to the Crown, the houses and lodgings forming part of the property being let out to various tenants at £95 1s. per annum. There was a French Church in the Savoy, which Pepys attended on September 28th, 1662, and later a German Church, the frequenters of which in 1736 addressed a petition to the Lords of the

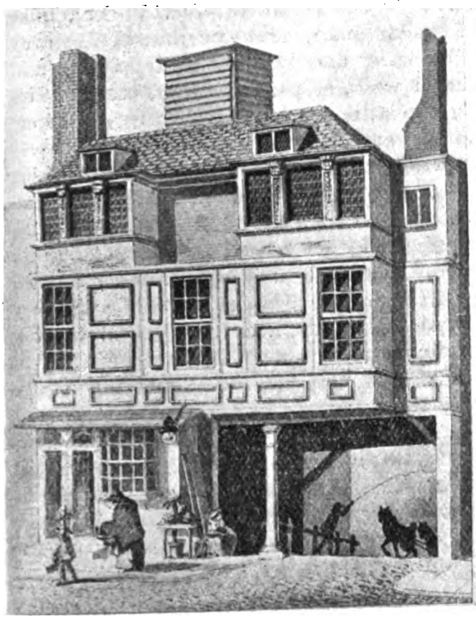

FIG. 13.—Durham House, Strand.

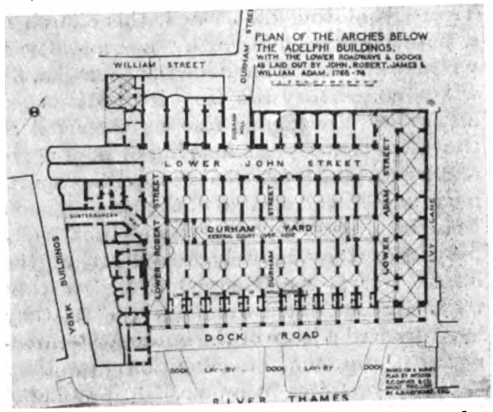

FIG. 14.—Plan of the Arches below the Adelphi Buildings.*

FIG. 15.—Flashlight View inside the Adelphi Arches.

FIG. 16.—Adelphi Terrace.

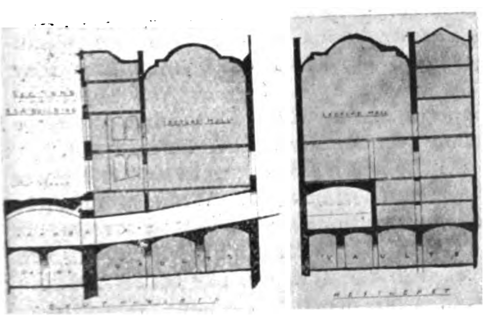

FIG 17.—Section through the Society's House.

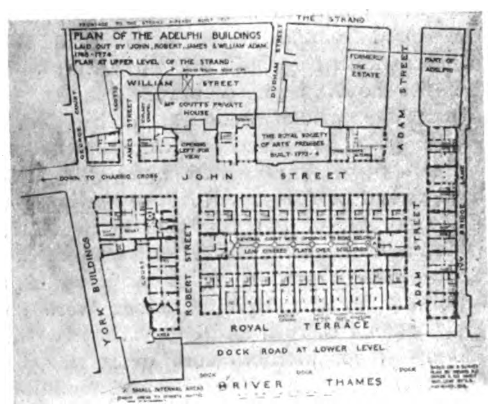

FIG. 18.—Plan of the Adelphi Buildings.*

*Figs. 14 and 18 are reduced from "The Architecture of Robert and James Adam," by A. T. Bolton, Curator of Sir John Soane's Museum, by permission of *Country Life*.

Treasury, stating that "near this church is a house now inhabited by a coal-heaver, whose wife washes linen for the barracks, by whose noises they are frequently disturbed at Divine Service, and also by the smell of the soapsuds. By the keeping of hogs there and by the smell proceeding from the apartment underneath several of the congregation were kept away from church," and they pray that they may have a lease of the house. It is satisfactory to know that by a warrant dated June 28th, 1736, they were granted a lease of the house for "threepence per annum, on condition that they kept the premises in repair." The Chapel Royal, Savoy, is the only part of the old building left, and that has been extensively restored after a fire which took place in 1854. Next to the Savoy was another Worcester House, frequently mentioned by Pepys, which was rented by Lord Clarendon at £5 per annum.

Leaving Durham House for the moment, we come next to York House, which was originally the site of the Inn of the Bishops of Norwich, but in Queen Elizabeth's reign the Archbishop of York got possession of it. Later on it was the residence of Lord Bacon, the Keeper of the Great Seal, and in 1624 the site was granted by King James to George Villiers, Duke of Buckingham, who pulled down the old building and commenced a new house, of which the water gate and stairs at the bottom of Buckingham Street, attributed to Inigo Jones, but more probably designed by Nicholas Stone, master mason to King James I., remain. In 1672 the Duke sold the whole site to some speculators, who developed it and commemorated in the streets which they laid out the names and titles of the Duke with an amusing thoroughness. The whole area was called York Buildings. We find a George Street, Villiers Street, Duke Street, Buckingham Street, and Of Alley. An Act of Parliament (29 Geo. II. c. 34) was passed in 1724, which recites that "The terras walk and the water gate belonging to York Buildings adjoining to the River Thames were so greatly gone to ruin and decay that it will require a considerable sum of money to repair and rebuild them;" and enabling certain trustees "to levy a tax on the inhabitants and proprietors of York Buildings, that is to say, George Street, George Alley, Villiers Street, Buckingham Street, Of Alley, and such other houses as were formerly the estate of Geo. Villiers, Duke of Buckingham, for the purpose of effectually supporting and keeping in repair the said terras walk, steps, causeway, etc." This terrace still exists approached by steps from Villiers and Buckingham Streets.

A little further west on the site of Charing Cross Station Sir Edward Hungerford had a house. Pepys in his Diary records the burning of this house on the 25th April, 1669. The site was afterwards occupied by Hungerford Market, which was very conveniently supplied from the river at a landing stairs there. It may be news to many that the present suspension bridge over the Avon at Clifton originally spanned the Thames here. Just below Hungerford House was a cul-de-sac running down to the river called Spur Alley, afterwards named Craven Street, much frequented by lawyers. James Smith, one of the authors of the "Rejected Addresses," wrote thus of it:—

"In Craven Street, Strand, ten attorneys find place,
And ten dark coal barges are moored at its base;
Fly, Honesty, fly! seek some safer retreat,
For there's Craft on the river and Craft in the street."

These lines brought forth the following rejoinder:—

"Why should Honesty fly to some safer retreat,
From Attorneys and barges—'od rot 'em?—
For the lawyers are *just* at the top of the street
And the barges are *just* at the bottom."

The last of the large houses on the river front was Northumberland House (Fig. 7). This was on the site of a mansion built in 1600 by the Earl of Northampton; he left it to the Earl of Suffolk, who re-named it after himself. The third Earl gave it to his brother-in-law, the Duke of Northumberland, for whom the river front was rebuilt by Inigo Jones. I dare say many may remember the old Strand front and the lion, which in the imagination of some people occasionally wagged his iron tail.

On the north side of the Strand there was not so much of interest. Wimbledon House may be mentioned, which stood somewhere just east of St. Martin's Church. It was erected in the 16th century by Sir Edward Cecil, who became Viscount Wimbledon, was partly burnt down in 1628, and entirely demolished early in the next century.

Then there was a house belonging to the Duke of Bedford, erected in 1582, with very large gardens running back to the Convent Garden of Westminster Abbey, now called Covent Garden. This occupied the site of Bedford Street, Southampton Street, and Exeter Street, and was pulled down in 1704. Part of the site was afterwards occupied by Exeter Change, a congeries of shops, the upper rooms being occupied by a menagerie of wild beasts. Close by was a large house occupied by Lord Burleigh, and afterwards called Exeter House, the name surviving in Burleigh Street. Exeter Hall was built on the site of this house. We then come to St. Mary-le-Strand, one of Gibbs' churches, which was built after an older church dedicated to St. Mary and the Innocents on the south side of the Strand had been taken down in order to build Somerset House. Holywell Street—which many of us can remember—and Butcher Row (Figs. 8, 9, 10 and 11) occupied narrow strips of land north of The Strand close to St. Clement Dane's Church. There were some very picturesque old houses near here, one owned by Lord Beaumont having been occupied by the Duke of Sully, Ambassador to James I. in 1603. Close to St. Clement Dane's originally stood Strand Cross, where for many years the Justices Itinerant without London used to sit and try legal cases, and after its removal a lofty Maypole was set up here. This is referred to in the well-known lines from "The Man of Taste," by the Rev. John Bramston, published in 1733:

"What's not destroyed by Time's devouring hand ?
Where's Troy ? and where's the Maypole in The Strand ?"

This was removed to Wanstead in 1718 by Sir Isaac Newton.

Having finished our peregrination of The Strand, we must now return to Durham House on the site of which we are assembled this evening (Figs. 12 and 13). Pennant says it was originally built by Anthony de Beck, Bishop of Durham, in Edward the First's reign, and if so it must have been almost contemporaneous with the Savoy Palace, but at any rate it was enlarged and almost rebuilt by Thomas Hatfield in 1353, and continued to be the London residence of those prelates till the reign of Henry VIII. That prince of iconoclasts ordered Tunstal, the then Bishop, to surrender it, giving him in exchange the royal house of Coldharbour in Eastcheap, which had been bestowed by Richard III. on the newly incorporated Society of Heralds. Edward VI. granted the house to his sister, afterwards Queen Elizabeth, but it is not certain that she ever lived in it. Dudley, Earl of Northumberland, occupied it in 1553, and the marriage of his son, Guilford Dudley, with the ill-fated Lady Jane Grey was solemnized here. She went from Durham House stairs by barge to the Tower, where she was proclaimed Queen on July 10th of that year, and soon after she was again taken to the Tower to be beheaded on February 12th, 1554. Queen Mary, who was a strong Catholic, endeavoured to undo many of her father's acts of confiscation, and she managed to get Tunstal re-instated for a short time, but when Elizabeth came to the throne she turned Tunstal out again, and Walter Devereux, first Earl of Essex, lived here for a short time. About 1583 the Queen granted the use of the house to Sir Walter Raleigh, who occupied it for about 20 years.

King James, soon after his accession sent a letter dated May 30th, 1603, t the Lord Keeper of the Great Seal, in these words: "We require you to give order to our Attorney General or some other of our learned Counsel to give warning and commandment to Sir Walter Raleigh Knight, and Sir Edward Darcy to delive quyet possession of the house called Duresme Place to the said Bishop of Duresme or to such as he shall appoint to receive it in his name." Sir Walter was very indignant and sent a spirited reply to the Lord Keeper dated June 9th, 1603. He writes: "I received notice requiring me to deliver the possession of Duresme House to the Bishop of Duresme before the xxivth day of June next. This letter seemeth to me very strange, seeinge I have had possession of the house about xx years. . . I am of opinion that if the King's Maiestie had required this house or the like from the meanest gentleman and servant he had in Inglonde that his Maiestie would have given six months' time for the avoidance, and I do not know but the poorest artificer in London has a quarter's notice to him from his landlord. . . Now to cast out my hay and oats into the streete at an houre's warning and to remove my family and stuff in xiii dayes after is such a severe expultion as hath not bynn offered to any man before this daye." Raleigh, however,

had to give it up and the Bishop took possession. The appurtenances of the house must soon have got into a ruinous state, as we read in 1609 that "the suburbs between London and Westminster had many ruinous pieces of building which age had worn out." Among the rest the Lord Treasurer erected out of the rubbish of the old stables of Durham House a goodly brick fabric to be rival to the old Exchange which the King by his presence dignified by the name of "Britain's Bourse." It is amusing to find that the city merchants of the Royal Exchange petitioned the King against this as they feared it would damage their business. The pretentious name did not, however, bring success to the venture and the building had a decaying and finally very unsavoury existence till it was pulled down about a century later. Durham House itself continued to be occasionally occupied by the Bishops till 1640, but soon after an Act was passed (16 & 17 Car. I. c. 35) "for the assuring of a Messuage called Duresme alias Durham House and certain stables, part of the possessions of the Bishops of Durham unto the Rt. Hon. the Earl of Pembroke and Montgomerie and his heirs at a yearly rent of £200 per annum to said Bishop of Durham and his successors in lieu thereof." The Ecclesiastical Commissioners still receive this rent from Mr. Geo. Drummond, the present owner. It was used as a barracks by the Parliamentary troops during the Civil War, and about the time of the Restoration was pulled down. A new street—the present Durham House Street—was formed leading out of The Strand down to another new street parallel with The Strand called Durham Yard. Here were erected several large houses, and in the latter part of the 17th century many titled persons date their letters "from my lodging in Durham Yard." Some of the Government Offices were situated here, and Pepys, in his Diary, mentions the fact that he went to the office of the Commissioners and Accountants in Durham Yard. The Strand was now becoming a more important thoroughfare. Britain's Bourse, which had become a great nuisance, was pulled down in the first half of the 18th century, and new buildings and shops were erected on its site, one of which became the well-known Bank of Coutts. The garden part of the site soon became very dilapidated and ruinous, and suggestions were put forward for forming a fine square facing the river; and a splendid scheme it would have been. But now there appeared upon the scene

"Four Scotchmen by the name of Adams,
Who keep their coaches and their madams,"

in the words of a lampoon of the day. These four brothers, Robert, John, James and William, sons of a Scotch architect, the author of the Vitruvius Scoticus, had influential friends and soon got a large practice in London. They promoted a very ambitious scheme, which was no less than doing away with the sloping ground from the Strand to the River for the whole distance between York Buildings and the Savoy, and raising the area to the Strand level, laying out new streets and forming a fine terrace facing the Thames. The property had passed into the hands of the Duke of St. Albans, from whom it has descended to Mr. Drummond, the present holder, and the brothers negotiated a lease from the Duke's trustees for 99 years from Lady Day 1768, at a ground rent of £1,200 a year. One cannot believe that any of the brothers in the slightest degree appreciated the gigantic magnitude of the task they had undertaken. The total area of the site was over 140,000 square feet, and The Strand level was about 40 feet higher than the old wharves just above high water mark. Thus it was necessary to construct a series of enormous arches, springing from huge brick piers, the foundations of which had to be taken down to a solid bottom (Fig. 14). The whole of John Street and Adam Street are on arches built over other streets at a lower level, and under these again are arched vaults. The houses on each side of John Street and Adam Street, the Adelphi Terrace and Robert Street are all constructed in this way. The Adams seem to have hoped that the Government would occupy all these subterranean arches for storing ordnance and other things, but they were disappointed. Much of their financial difficulties arose from this. The arches are now used as wine stores, and they constitute one of the most curious and interesting sights of London, reminding one of much of the work of Imperial Rome. The arches are all groined and the work was splendidly executed, much of the brickwork being now as good as ever (Fig. 15).

Considerable difficulties were also met with owing to high tides flooding the foreshore and the water penetrating into the

arches, and an Act was passed (XI. Geo. III., c. 34) which recited that "the extra width of the Thames between Westminster and Blackfriars Bridges and the consequent sluggishness of the current contributed to the formation of a very extensive sandbank on the north shore of the river, rendering the access to the wharves and grounds very difficult," and it authorised the four brothers and certain others "to enclose and embank the river from the south-west corner of the buildings commonly called The Savoy as far as the south-east corner of the terras belonging to York Buildings." The Lord Mayor and the citizens of London petitioned against this Act, but it was passed subject to the proviso that the citizens of London and also the Dean and Chapter of the Collegiate Church of St. Peter in Westminster, *i.e.*, Westminster Abbey, were to be at liberty to have their privileges and rights tried in a Court of Law. This embankment still exists at the back of the present Embankment Gardens, and forms a roadway on the river side of the arches under Adelphi Terrace (Fig. 16). The houses on this terrace, with its commanding position and splendid view over the river, were greatly in demand as residences, and many well-known persons lived there. Among them may be mentioned David Garrick, of whom Miss Burney wrote in her diary in April, 1772: "We were so happy in being let in at Mr. Garrick's and saw his new house in the Adelphi, a sweet situation." Topham Beauclerk, the friend of Johnson and Boswell, and Rowlandson, the artist, also lived here; Isaac Disraeli lived in The Adelphi, but his more famous son, Benjamin, was born just after he had left.

Adelphi Terrace did not find favour in the eyes of Horace Walpole, who likens it to "a warehouse laced down the seams like a soldier's trull in a regimental old coat." Even now, although the original design has been much altered for the worse, this opinion would not be confirmed. The detail of the work is admirable, but the general effect is somewhat flat.

The negotiations which led to the erection of the building in which we are assembled have been told in detail by Sir Henry Wood, and I will only summarise them here. An agreement between the Brothers Adam and the Society was entered into on March 21st, 1772, under which they undertook to build premises for the Society on condition of receiving £1,170 in cash and a rental of £230 a year for 91½ years: the lease was finally signed on May 3rd, 1775. The brothers appear to have estimated the cost of the building at £5,000, but it must have far exceeded this sum, looking at the massive sub-structure.

There are many peculiarities in this building, and the probability is that a good deal of the extensive vaulting under the street and buildings had been commenced before the actual plan of these premises was prepared. In the course of the work recently carried out here we came across a 3ft. thick wall under the vestibule, which was carrying nothing at all. Between the floor of the library and the vaults which have been conveyed to the Society as part of the freehold, there is a public street running right through the building from the back wall of the Meeting Room to John Street, and the whole of the buildings in the two houses used by the Society are built either on the crown of the arch over this street or on the crown of other vaults, the solid ground not being reached till we get to the floor of the vaults nearly 40 ft. below the level of John Street (Fig. 17). The building, as it existed six months ago, was not materially different from the original design of the Adams. The staircase was slightly altered and the front of the building is without the ornaments on the pediment. The alterations which we have recently carried out under Mr. Bolton's direction, consist of the opening up of the staircase to the vestibule, the enlarging of the latter and the restoration of the library approximately to its former condition, thus, we hope, greatly increasing the amenities of the room. This meeting room has been re-seated and the entrance to it altered to allow of the rise of the seats, but nothing has been done incongruous with Adam's work.* Looking at all the structural difficulties involved in this Adelphi work, it is not to be wondered at that the Adams got into very serious financial difficulties

*May I be permitted here to interpolate a few words as to the Society's position? There is some danger that the munificent gift of the anonymous benefactor which has enabled us to purchase the freehold of these premises may lead the Fellows and friends of the Society to think that no more contributions to the Building Fund were required, but this is far from being the case. The cost of the improvement and embellishment of the premises is very considerable and the Council earnestly hope that those members who have not yet contributed to the Building Fund may see their way to do so in order that the activities of the Society may not be unduly cramped.

In 1774 they published a pamphlet admitting that the enterprise on which they had embarked was too great for their personal fortunes: they offered for sale by auction all their art collections, statues, vases, etc., but most of them appear to have been bought in, and in order to provide funds to complete the works they obtained an Act of Parliament, enabling them to dispose of their landed property by a lottery, the successful issue of which got them out of the worst of their difficulties.

This is not the occasion to discuss the work of the Brothers Adam: this has been done very efficiently by Mr. Arthur Bolton in his recently published monumental work. They have left their mark not only in the Adelphi, with which their names will be for ever associated, but in many other parts of London and all over the country, and there can be no doubt that their work stands out as the predominant architectural feature of the 18th century. Robert and John were the principal designers, but William Adam has left us in London one charming little bit of building. I have mentioned Coutts' Bank in The Strand. These premises ran down to William Street (now a part of Durham House Street), and Thos. Coutts wanted to connect them with another house on the south side of the street, which he also occupied. Accordingly he got an Act passed by Parliament (39 Geo. III., c. 1) authorising him to throw a bridge across the street to connect the two buildings. This was designed by William Adam, and, fortunately, it still exists, but only by sufferance of the London County Council. I wonder how many Londoners have ever seen it. The interior of Coutts' house was also enriched by the Adams, and Coutts had sufficient influence with them to stipulate that in their lay-out of the Adelphi buildings a gap should be left through which Coutts from his parlour could get a view of the river. This is shown clearly on one of my slides (Fig. 18).

I have now finished my attempt to bring before you some of the old-world aspects of the immediate neighbourhood of the site of this building, and, looking at the very small area of the district with which I have been dealing, and seeing how full of interest it is, one gets some slight notion of how intimately bound up with the history of our country every portion of this great city is. The memorials of Old London are decreasing with appalling rapidity every year. No doubt this is inevitable; the picturesque must give place to the utilitarian, and yet—and yet—one looks back longingly to many old bits of London, even to the original Regent Street, which is only about 120 years old. And now, within the last few weeks, we have heard disquieting rumours that the site of the Adelphi Terrace may be sold for the erection of a new Masonic Hall. In my opinion, this would savour of rank sacrilege, and I trust that every effort will be made to prevent it. Surely it is incumbent on us not only to preserve records of the past, but to prevent unnecessary destruction of the old that is left us. It is of good omen that the London County Council, by its admirable monographs on the various districts of London—which I hope will be continued with the same comprehensiveness as the volumes which have already appeared—is looking after the old records, while the London Society—a comparatively young body—is doing yeoman service in rousing the public interest in this city so as to preserve what is old but not worn out, and to ensure that the new London shall be worthy of the dignified traditions of the old. By the united efforts of these two bodies, backed by the enlightened support of its citizens, may we not hope that the London of the future will merit the words of eulogy addressed to the London of the past by William Dunbar, the Scottish Rhymer, four hundred years ago, who wrote:

"O Toune of tounes patrone and not compare
London thou art the floure of Cities all."

DISCUSSION.

MR. E. NEWTON said he would not like the opportunity to pass without expressing his personal thanks to the lecturer for all he had said about the Strand. Although Mr. Slater did not state it in his paper, he knew very well that the Strand contained more old buildings than any other large thoroughfare in London. The Strand was not the oldest thoroughfare in London, as Cheapside might be said to hold that distinction, yet in traversing the Strand one could see several 17th century houses still existing. They were not very large, but the backs and the roofs remained; the fronts alone had been changed. Another interesting fact about the Strand was the numbering of the houses. There was no No. 1. The Strand commenced with No. 6. Then there came a blank where Charing Cross railway station now stood, and there was another

blank at Somerset House. The old numbers in the Strand had existed as such for over 150 years. He also desired to thank the London County Council for all that that body had done in commemorating old London houses by placing tablets thereon. That idea had been first started by the Royal Society of Arts nearly 50 years ago, and when funds had not allowed the Society to continue the work the London County Council took it up with very good results indeed, thus letting those of the present generation who ran also read about the various celebrities who had lived before. With reference to the naming of streets, the L.C.C. was the supreme authority. The various boroughs suggested names, but the matter of the naming of the streets was governed solely by the L.C.C. who, wherever possible, tried to retain the old and historic names. In the case of one street nn particular they had given it back its old title, amely, "Petit France."

The Chairman, in moving a hearty vote of thanks to the lecturer for his most interesting address, said nothing was so fascinating to a Londoner as to listen to stories of the past connected with that part of London with which he was most intimately acquainted, and it was still more fascinating when those stories were illustrated by views such as Mr. Slater had exhibited that evening. Personally he had found the paper exceedingly interesting by the fact that he had been for some years High Steward of His Majesty's Manor and Liberty of the Savoy, part and parcel of the Duchy of Lancaster. That Manor had a Court Leet once a year in order to see that His Majesty's boundary marks were not moved, and to present nuisances that might exist within the Manor and Liberty. The interest which the members of the jury,—16 in all—and also the burgesses of the Manor, took in its ancient history was very striking. Mr. Slater had alluded to that Manor—or rather to the Palace of the Savoy—as having been granted in the 30th year of Henry III. to the King's wife's uncle Peter of Savoy, and as then coming to Edmund of Lancaster, from whom it had descended to our present King. The Manor of the Savoy extended over a considerably larger space than where the old castle had been. It extended from the gardens of the Middle Temple through a cellar in Child's Bank, through Messrs. Twining's house up to Clare market, over the stage of the Lyceum theatre (where Sir Henry Irving used always to entertain the jury with cake and wine when they were beating the bounds) to the boundaries nf the Cecil Hotel—old Salisbury House—where the boundary mark had been moved with the building of the Cecil Hotel and where, on the presentment of the jury, a wall had been pulled down and the boundary mark reinstated in or near its proper place, down to the Embankment and so along to the Middle Temple gardens again. It was a wide piece of land, originally with a castle upon it governing the curve of the river, but otherwise, except for the road which had been shown in Mr. Slater's drawing, apparently a sandy waste in part and a marshy waste in another part. It was undoubtedly in a place where the King's Uncle was very close to the citizens of London on the one side, and also it was a sort of protecting bulwark for the King in his Palace of Westminster if those citizens of London had chosen to come out and go along the Strand, giving to the Uncle the opportunity of taking them in the rear. The history of the Manor went back for all those centuries. The proceedings of the court were written in a book, evidently a successor of a previous book, beginning in 1735, and the proceedings showed how the beasts, to which Mr. Slater had referred, on Exeter Exchange had to be examined and also how they were presented over and over again as a nuisance. They also showed how, in the prison of the Savoy, French prisoners at the end of the 18th Century were chained together, and how a fraudulent gaoler was heavily fined for only allowing them clean straw once in every three months and for allowing one of them to have scarlet fever without being unchained from the prisoners on either side of him. One read of the horrors of Russian and Turkish prisons; yet that happened only 150 years ago in this country. Also the proceedings showed how the owners of the land where those big houses had been built were fined over and over again—particularly the Dukes of Norfolk—for not keeping the stairs to the river in proper condition, and for allowing various nuisances to exist in the Strand. There were also ale tasters and officers to examine weights and measures, a bailiff, a beadle, a make, and two burgesses for each ward, in addition to the jury of "resiants" within the precincts of the Manor.

It was in that kind of way that old London had been governed. Very often, when houses fell into disrepute and the property became bad, the freehold owners of the land were mulcted by the people themselves presenting the trouble, and also taking, under the law, the punishment or "amerciament" into their own hands.

The ancient court of the Savoy was stated by Maitland and Pollock, in their book upon Mediæval Law, as being one of those interesting courts which had remained from the period before the jury system in its modern form had been established, when the people presented the nuisance, and not only presented the nuisance but amerced or made the fine themselves—a matter which the common sense of the community would perhaps bring within a reasonable amount; but certainly as late as the year 1830 the citizens of the Strand, or the jury of the Savoy, got so incensed with the then Duke of Norfolk for not

repairing one of the steps down to the river, that finally they fined him £50, which the Duke paid.

Those were just a few instances of some of the interesting things that could be found in a district like the Strand, and in London everywhere—and that was only within the last few centuries. Mr. Slater had alluded to Roman baths on the site very near to where the house of the Society of Arts was. That carried one's mind back as many hundreds of years beyond the period to which he had just been alluding as they were now from the reign of King Henry the Third.

He might add that the continuity of the Savoy could be illustrated by its present burgesses, all connected with the Manor, all known within its precincts. They were (1) Viscount Hambleden, head of the firm of W. H. Smith and Sons. His father, Mr. W. H. Smith, leader of the House of Commons, had also been a burgess. Their head offices were within the Manor. (2) The Chaplain of the Savoy. His predecessors had continually sat as burgesses. (3) Mr. H. Twining, of the great tea and banking house of Twinings. His family had supplied burgesses for over 150 years. (4) General Sir Fabian Ware, late editor of the "Morning Post," whose offices were within the Manor. (5) Mr. H. A. Gwynne, the present editor of the "Morning Post." (6) The Hon. Sir Charles Russell, Bart., who practised as a solicitor within the Manor. (7) Mr. Fane, a partner in Child's Bank, which preserved one of the boundary stones; and as the junior burgess there had been selected (8) The Rt. Hon. Sir Joseph Cooke, High Commissioner for Australia, thus linking the new with the old world, Australia House being within the Manor. The Bailiff, Mr. R. G. L. Willoughby, was the son and grandson of former bailiffs.

As High Steward he himself gave an annual dinner at the Savoy Hotel to the Chancellor of the Duchy, the Vice-Chancellor and the Attorney-General of the Duchy, and to the Burgesses and Bailiff of the Manor. The table was always decorated with the red roses of the House of Lancaster, and the only toast was "The Duke of Lancaster, Lord of the Manor and Liberty of the Savoy." The jury used to have a dinner, but in lieu thereof now received an allowance from His Majesty the King.

He was sure the audience would join him in thanking Mr. Slater for the pleasant evening he had given them and for the paper which he had been good enough to deliver to the Society.

The vote of thanks was put and carried unanimously.

The Author, in reply, said if the audience had obtained as much interest from listening to the paper as he had got from preparing it he was perfectly satisfied.

THE MADRAS LEATHER INDUSTRY.

Lecturing at the University of Madras, Mr. K. C. Srinivasan, M.A., F.C.S., gave some interesting particulars concerning the Madras leather industry. It is the most important industry of southern India. Of the manufactured articles exported in the year 1920-21 to the amount of 750 lacs of rupees, not less than 250 lacs of rupees were accounted for by the export of leather alone. The results are more interesting when compared with the figures for the whole country. In 1919-20, for example, India exported leather to the value of 12 crores of rupees, of which Madras contributed as much as 10 crores of rupees.

Madras Half-Tans.

The Madras leather industry depends upon industries like Agriculture and Silviculture rather than on supplies of coal and iron. This is due to the fact that the tanneries of southern India do not carry the manufacture of leather to completion but export it in a semi-finished state for further treatment in European tanneries. The manufacture of leather from hide substances may be treated under three distinct heads—preliminary processes, tanning processes and finishing processes. Of these the Madras leather industry comprehends but the first two. Of the twenty or more operations involved not more than half a dozen are carried forward in the Madras tanneries. This is due to the fact that the Madras tanneries depend for their markets upon foreign manufacturers' finished leather and leather goods. Were they to contemplate the manufacture of finished goods in India all the difficulties of modern industry such as the investment of capital in costly machinery, prohibitive over head charges for skilled technical staff and severe European competition would result.

Research in India.

Research in India, therefore, has been directed towards the investigation chiefly of the utilisation of the by-products of the Madras leather industry. At every stage in the manufacture of leather the skill of the well trained leather chemist is called into requisition. Complex organic substances like hide matter, the tanning principles and their degradation products which occur in what is known as the colloidal state of matter offer to the chemist work of considerable difficulty. Knowledge of bio-chemistry and bacteriology is essential for the investigation of the simplest problems, and modern advances in electro-chemistry and colloidal chemistry are finding increasing application in leather manufacture.

Chrome Tanning.

Work on leather in India was commenced by Sir Alfred Chatterton, the first experiments in chrome tanning being carried out under his instruction by Mr. N. S. T. Chari, M.A.,

then chemist in the Department of Industries and now one of India's foremost industrial magnates. The history of Chrome leather is a separate chapter by itself and cannot be confused with the Madras leather industry which comprehends no more than the manufacture of Avaram-tanned light leathers for export.

Search for an Avaram Substitute.

The economic production of Indian half-tans has rightly attracted the attention of the research worker in India. During the war supplies of Avaram bark proved inadequate for the needs of the industry, and chemical research was directed towards the discovery of a proper substitute. A careful examination of the tan-stuffs that abound in the forest of Southern India disclosed the existence of at least two tanning materials worthy of detailed investigation. Infusions of these tan-stuffs gave good leathers, no doubt, but differed from the Avaram-tanned leathers in at least one important respect, which prevented their finding acceptance in the Madras tanneries. The leathers made of these tan-stuffs were more fully tanned and did not allow of as great a margin of profit to the European manufacturer as the Avaram-tanned leathers.

Tannin Extracts.

Another subject which attracted the attention of research chemists in India was the manufacture of tannin extracts. It will be easily realised what great advantages would accrue to the European manufacturer if he were in a position himself to carry out the tanning with Avaram for which he has now to rely upon the Indian tanneries. The Indian sun synthesises in the laboratory of the living cell more wonderful tannin complexes than were ever turned out of a German factory. Attempts have therefore been made times without number to distil the essences of these Indian tan-stuffs and carry them away in a condensed and available form for use in foreign countries. But it was found in the case of the Avaram that even the most delicate treatment failed to give an extract which on subsequent dilution yielded a solution having the same properties as a fresh infusion of the bark.

Spent Tan-Stuffs.

Another interesting line of research was directed towards the utilisation of the large quantities of spent tan-stuffs that are the by-products of South Indian tanneries. An attempt towards further extracting tannin from spent bark showed that the yield obtained was incommensurate with the cost of treatment. Nor was it possible by suitable treatment to convert the spent bark into valuable pulp for card-board manufacture. Destructive distillation however, yielded a product very rich in tar and inflammable gases that could be burnt to afford motive power.

Leather and Hide Waste.

The question of converting hide and leather waste into glue and gelatine has occupied considerable attention in recent years. There are three difficulties at least with which the glue manufacturer in India is beset. They are (1) liquifying organisms (2) low temperature jellying and (3) low temperature drying. The literature on the subject of glue manufacture is very scanty and the only authorities, Rideal and Lambert, lay down more or less clearly, that glue manufacture is impossible in the tropics. Add to this the fact that European manufacturers observe considerable secrecy and that it is impossible to acquire any knowledge of the methods adopted or the machinery used in foreign glue factories.

A new method of manufacture had, therefore, to be devised which comprehended suitable treatment of dilute glue solution so as to make the latter set at tropical temperatures. Several lines of investigation that were carefully followed led to the desired result, and the process which involves the addition of sulphates and double sulphates of aluminium and other metals has been adopted with considerable success. The discovery was due to the recognition of the significance of the rather well-known fact that alum solution hardens photographic gelatine films, which, put differently, may be taken to have increased the setting point of the gelatine jelly, that is to be found on one side of the wetted photographic plate. Considerable work has also been done upon the use of antiseptics in glue and gelatine manufacture and in the utilisation of enzymatic reactions in cutting down the cost of production. The research station established by the Department of Industries in Madras as a result of these experiments has been producing glue of excellent quality at competitive prices.

THE ALFA INDUSTRY IN ALGERIA.

Alfa is the Algerian name of what is known in trade circles as esparto grass. Its botanical name is *Stipa tenacissima*, or tenacious feather-grass. Besides the Arabic term halfa, the natives of Algeria name it senaug, soenaghr, and sengha.

From a report received from the United States Consulate in Algeria, it appears that the alfa region in Algeria covers several million hectares, (hectare = 2.47 acres,) occupying particularly the highland zone. The plant grows at an altitude of 1,000 to 4,000 feet, but does not thrive where the average annual rainfall exceeds 23.62 inches.

Alfa grows in eastern Algeria in the Department of Constantine, in central Algeria in the Department of Algiers, and in western Algeria in the Department of Oran.

Alfa districts in the Department of Constantine comprise Tebessa, Bir el Ater, Mides, Jebel

Chechar, Sidi Abid, Nacoeh, El Amra, Jelal Ahmarkhradou, Mizab, Tanzoult, Oulah, and Guerra. Streams of fresh water are numerous and the distance to seaports averages about 124 miles.

In the Department of Algiers, alfa districts comprise Djelfa, Megzem, Jebel Sahari, Zenina, Chabet Zamra, Jebel Amour, and Boukahil. Several streams cross a region where alfa is plentiful, where distance from the sea varies from 125 to 200 miles, and where railways are not less than 65 miles distant.

The Department of Oran is the centre of alfa production and comprises the districts of Jebel Amour, Chebka de Kosny, and Chot Chergui.

In the zone of the Tafna sources, water is sufficient. The distance from the port of Oran is about 111 miles, viz., 24 from the fields of Lamoriciere, thence by rail for 87 miles.

In the region of Ain Skrouna the centre crossed by streams is 68 miles from the railway station of Kralfallah, which is about 130 miles from Oran—a total of 198 miles to the sea. Besides this obstacle a more serious one is the prevalence of malaria.

The nature of the soil and the altitude modify the qualities of alfa. Fibres from plants growing in siliceous land are hard and breakable, while sandy land gives fineness, light colour, length and strength. Iron in the soil accentuates the colour, and salt earths favour thickness of stem but produce less tenacious fibres.

Weight and size of leaf vary with altitude, the heaviest and largest growing on sandy clayish alluvia, the medium on steppes and highlands, and the lightest and smallest in mountainous regions.

According to its commercial uses, alfa is classified as (1) spartum alfa, for manufacture of ropes, mats, etc.; (2) that used for paper making; (3) a variety for the basket trade.

Analysis of Spanish esparto and African alfa shows that each is susceptible of giving nearly 50 per cent. of its weight in cellulose (48.25 per cent. for the Spanish and 45.8 per cent. for the African).

Compared with the unripe leaves the yellow leaves of alfa or esparto are less rich in cellulose, and the paper from them is less resistant; leaves that grow ripe are heavily charged with silica and oxide of iron, which render whitening more difficult.

Kaolin, used as loading in newsprint and lower grades of writing paper, is also found in Algeria in large quantities.

The two difficulties which made the manufacture of paper pulp in Algeria seem impracticable until of late—excess of chalk and salt in local waters and the high percentage of liquid required for preserving and transporting the finished and whitened pulp—have been overcome through the researches of a French engineer. The result is a new type of pulp called "demi-demi," which can be pressed into minimum volume and transported dry. It can be kept indefinitely and used as required by diluting, washing, finishing, and whitening the dry product. Two cubic meters (2.615 cubic yards) of demi-demi pulp, weighing 1,000 kilos (2,204 pounds avoirdupois), represent the equivalent of from 10 to 12 cubic meters (13.07 to 15.69 cubic yards) of raw alfa weighing 2,000 kilos (4,408 pounds), thus effecting an economy in freight of 50 per cent. in weight, or 500 to 600 per cent. in volume.

French groups have organised for making pulp from alfa at a minimum cost of production; but as there is practically no coal in North Africa and hydro-electric resources are undeveloped, and as water sufficient for complete treatment is unobtainable in certain important alfa zones, it is thought by many that the Algerian annual output of alfa pulp will be less than the demand for several years and that prices will be fairly well maintained.

It is reported in the local press that a company in Algiers, with a capital of 2,000,000 francs, is going to build its first factory for paper pulp in the alfa region at Ain el Hadjar, near Saida, on the railway from Oran to Colomb-Bechar.

Algerian exports of alfa in 1920 amounted to 53,982 metric tons, valued at about 13,500,000 francs. This was but little more than half the quantity exported in 1910 and considerably less than half that of 1912, the year of greatest export, when the quantity reached 117,632 tons and the average price was 75 francs per ton, or a total value of over 8,800,000 francs. The year 1919 was the worst, exports falling off to 5,888 tons, chiefly through lack of railway facilities from centres of production to seaports.

In general, about 80 per cent. of all alfa exports have been through the ports of Oran and Arzew, about 10 per cent. through Bona, and the remainder from Algiers, Philippeville, and Bougie.

The principal customer for Algerian alfa has been England, which absorbs from 90 to 95 per cent. of the exports.

MOTOR CARS IN CHINA.

The lack of modern roads accounts for the fact that although motor cars have been sold in China for 20 years only a small number of them are now in operation, and the market is still very limited. Recent estimates place the mileage of the improved city streets and roads of China at 500 and the passable dirt roads in the rural districts at 1,200. The number of passenger cars, motor trucks and motor buses in operation probably does not greatly exceed 8,000.

Apart from the lack of roads, the cost of fuel oil is of importance. The price of petrol varies from 1*s*. 8*d*. to 2*s*. 6*d*. per gallon in Shanghai

to £4 or more in Urga, Mongolia, the price increasing in proportion to the distance from the treaty ports and the correspondingly heavy expense of inland transportation. Urga receives its supply of petrol by camel trains across the Mongolian Plateau, the fuel being too bulky for transport by the existing motor car lines, which make the distance in one-eighth of the time required by caravans.

Regarded at first as a luxury, the motor car is now recognised in China as a necessity for rapid transit in cities, for suburban and inter-urban communications, for connecting railways with waterways, for feeder lines to railways and water routes, etc.

Another potent reason for buying is the fact that the Chinese like to make an impressive appearance. The possession of a motor car carries with it exceptional prestige, as the native official or business man who owns a high-powered, richly appointed motor car is greatly respected. Electrical fittings, accessories, and any new, ornate features of practical value make a strong appeal. This liking for display has resulted in an increasing importation of chassis for which bodies are manufactured in China, thus reducing the cost of the car and enabling the purchaser to have incorporated all the special body features he desires.

Road conditions away from the urban districts constitute severe tests on motor vehicles, and so far as light cars are concerned only the most substantial can stand the strain. Peking's frequent dust storms and cold winters make closed vehicles popular. Cars with a short wheel base and gears permitting easy change from medium to low speed are best adapted to the city streets, which are narrow and used by a great number and variety of native vehicles. The Chinese are skilled chauffeurs and excellent judges of distance, but because they do not pay adequate attention to the upkeep of their cars, it is essential to make the mechanism as simple as possible.

Taxicabs are gaining favour in Shanghai and Peking, which cover extensive areas and lack other facilities for rapid transit. Many companies, both Chinese and foreign, run cars for hire in these cities. Shanghai street-car lines serve the business section fairly well, but do not cover the outlying districts.

A fair number of electric passenger cars have been sold in Shanghai, where there are no steep grades; and this is practically the only type of motor car that to any great extent is owner-driven. Electric cars are liked by the foreign community, as the expense of their maintenance in Shanghai is lower than that of petrol-driven cars; but for the Chinese, who like high speed for pleasure rides, they are too slow.

A few motor trucks are employed in Shanghai for general hauling purposes. Both the international settlement and the French concession have motor fire-fighting equipment.

A good market for motor-cycles may develop from the fondness of the Chinese for bicycle riding; so far, however, sales have been limited by the absence of good roads, lack of mechanical ability among those who are able to purchase motor cycles, and the preference of Chinese for riding in parties of five or six.

Although there are now 13 plants building motor car bodies in Shanghai and one concern which has manufactured a complete passenger car, there is little probability that China will develop a motor car manufacturing industry in the near future.

According to a report by the U.S. Trade Commissioner at Shanghai, from which the foregoing particulars have been extracted, the outlook for motor-car sales in China was greatly improved at the end of 1921, when the Shanghai Automobile Show drew 25,000 visitors and resulted in £25,000 worth of business. Early in that year about 700 cars and 50 or more motor trucks, ordered in the high silver period of 1919-20, were lying on the docks at Shanghai, as were many more at other ports. By midsummer this stock had been fairly well cleared and new orders were being placed. So marked was the improvement by autumn that one firm in Shanghai reported more sales of passenger cars in October, especially higher-priced models, than during any one month for two years. This was attributed, however, to the mania for spending, then prevalent among operators in native produce and stock exchanges; the principal call now is for medium and low-priced cars.

In judging the eventual market for motor cars in China the Trade Commissioner estimates that, with an adequate mileage of good roads, possibly 500,000 Chinese officials, bankers, and merchants could be considered as prospective customers. Generally speaking, other native classes cannot afford to buy cars. Among the foreigners in China, Europeans usually prefer machines made in their own country; the American, Russian, and Japanese colonies might in time include possibly 10,000 future purchasers. The outlook for the near future is favourable.

Heavy stocks have been sold off, the good-roads movement seems to be making progress, and business in general has improved.

EXPERIMENTS WITH PULP FROM AUSTRALIAN HARD WOODS.

Experiments have been made by the Forest Products Laboratory at Perth, W.A., for ascertaining the paper-making possibilities of certain Australian hardwoods. These tentative experiments, writes the United States Vice-Consul at Sydney, establish the fact that the pulps from mountain ash (Victoria), blackbutt, spotted gum, mountain gum (New South Wales), karri (West Australia), and silky oak (Queensland) are all suitable for paper

making. While silky oak returned the most excellent results, the quantity of this timber is very limited. Among the other hard woods, of which there is an abundance in the Commonwealth, mountain ash was found to return the best pulp and produce the best grade of paper.

The experiments indicate that these hardwood papers are much stronger in almost every respect than a series of imported good office envelope and bond papers taken at random from the laboratory stock. The specimen paper from pulp of mountain ash was found to be stronger in bursting strength and considerably stronger in breaking strain than the choice imported papers.

Summarised, the report issued by the Laboratory shows that: (1) The beating of hardwood pulps has a very marked effect upon the paper produced from them; (2) paper stock suitable for numerous uses is obtained by a proper beating treatment; (3) paper produced from the pulp of eucalyptus, after having received the prescribed beating, is as strong as and in some cases stronger than good imported bond; (4) blending to give strength to the paper is not necessary, provided the pulp has received proper treatment prior to running over the machine; (5) in colour, feel, and rattle these hardwood papers are similar to the bleached papers commonly used for stationery.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK *

MONDAY, DECEMBER 4 .. Transport, Institute of, at the Institution of Electrical Engineers, Savoy Street, Victoria Embankment, W.C., 5.30 p.m. Mr. S. E. Garcke, "Passenger Transport by Road in Rural Areas."

Farmers' Club, at the Surveyors' Institution 12, Great George Street, S.W., 6 p.m. Annual General Meeting. Address on "Agricultural Shows, their present Functions and how they can be Usefully Extended."

East India Association, Caxton Hall, Westminster, S.W., 3.30 p.m. Mr. S. P. Rice, "The Hindu Outlook on Life."

Engineers, Society of, at the Geological Society, Burlington House, W., 5.30 p.m. Mr. W. Dinwoodie, "Wave Power Transmission."

Chemical Industry, Society of, at the Engineers' Club, 39, Coventry Street, W., 8 p.m. Dr. G. S. Robertson and Mr. F. Dickinson, "The Valuation of Insoluble Phosphate by means of a Modified Citric Acid Test."

TUESDAY, DECEMBER 5 .. Civil Engineers, Institution of, Great George Street, S.W., 6 p.m.

Colonial Institute, Hotel Victoria, Northumberland Avenue, W.C., 8.30 p.m. Mr. D. Bashott, "A Glimpse of the Union of South Africa."

Metals, Institute of (Local Section), Chamber of Commerce, New Street, Birmingham, 7 p.m. Mr. R. J. Redding, "Some Notes on Casting 70: 30 Brass."

Anthropological Institute, 50, Great Russell Street, W.C., 8.15 p.m. Miss E. Kemp, "The Aborigines of Western China."

WEDNESDAY, DECEMBER 6 .. University of London, South Kensington, S.W., 5 p.m. Sir Frederick Bridge, "Some Operatic Studies." Lecture II. "Pysche," by Matthew Locke (1673).

Geological Society, Burlington House, Piccadilly, W., 5.30 p.m.

British Academy, at the Royal Society, Burlington House, W., 5 p.m. Prof. G. Gordon, "Shelley."

United Service Institution, Whitehall, S.W., 3 p.m. Mr. L. G. Carr-Laughton, "The Battle of Velez Malaga."

Industrial League and Council, Caxton Hall, Westminster, S.W., 7.30 p.m. Mr. R. Young, "Difficulties in the Way of Increased Production."

Public Analysts, Society of, at the Chemical Society, Burlington House, Piccadilly, W., 8 p.m. 1. Messrs. E. W. Blair and T. S. Wheeler, "A Note on the Estimation of Form-and Acet-aldehydes." 2. Mr. C. H. D. Clark, "A Sliding Scale for the Convenient Titration of Strong Liquids by Dilution and Use with Aliquot Parts." 3. Mr. H. A. Peacock, "Note on the Presence of Sulphur Dioxide in Cattle Foodstuffs after Fumigation." 4. Mr. D. W. Steuart, "Some Observations with regard to the Unsaponifiable Matter and Sterols of Edible Fats." 5. Messrs. N. Evers and H. J. Foster, "Note on the Sulphuric Acid Test for Fish Liver Oils."

Public Health, Royal Institute of, 37, Russell Square, W.C., 4 p.m. Mr. C. W. Hutt, "Medical Inspection in Secondary continuation Schools."

St. Paul's Ecclesiological Society, 7, St. Andrew Street, Holborn, E.C., 8 p.m. Rev. A. Shirley "The Ruined Monastery of Poblet, near Tarragone, Spain."

University of London, University College, Gower Street, W.C., 6.15 p.m. Mr. A. W. Flux, "Foreign Exchanges (Lecture V.), Discount Rates and Exchanges."

THURSDAY, DECEMBER 7 .. Aeronautical Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.30 p.m. Prof. C. F. Jenkin, "Fatigue in Metals."

Ophthalmic Opticians, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 8 p.m. Dr. Critchley, "Heterophoria and Strabismus (Ettles Memorial Lecture)."

Royal Society, Burlington House Piccadilly, W., 4 p.m.

Chemical Society, Burlington House, Piccadilly, W., 8 p.m. Messrs. S. O. Rawling and W. Clark, "The Isoelectric Condition of Gelatin."

Chadwick Public Lecture, at the Royal Society of Medicine, 1, Wimpole Street, W. 5.15 p.m. Sir Arthur Newsholme, "Relative Values in Public Health." (Lecture I.)

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C., 6 p.m. Mr. A. M. Taylor, "The Possibilities of Transmission by Underground Cables of 100,000-150,000 volts."

Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.

Camera Club, 17, John Street, Adelphi, W.C., 8.15 p.m. Mr. B. Cox, "Landscape—A Pot-pourri."

University of London, at the London School of Economics, Houghton Street, Aldwych, W.C., 6 p.m. Sir Frederick Lugard, "Economic and Administrative Problems of the British Tropics." (Lecture III.)

Mechanical Engineers, Institution of (N. Western Branch), Memorial Hall, Albert Square, Manchester, 7 p.m. Dr. T. E. Stanton, "Some Recent Researches on Lubrication."

FRIDAY, DECEMBER 8 .. London Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5 p.m. Mr. H. A. Cox, "London before the Great Fire and Now."

Mechanical Engineers, Institution of (Yorkshire Branch), Philosophical Hall, Park Row, Leeds, 7.30 p.m. Dr. T. E. Stanton, "Some Recent Researches on Lubrication."

Astronomical Society, Burlington House, Piccadilly, W., 5 p.m.

Metals, Institute of (Local Section), University St. George's Square, Sheffield, 7.30 p.m. Mr. W. R. Barclay, "Cobalt."

Malacological Society, at the Linnean Society, Burlington House, Piccadilly, W.

Physical Society, at the Imperial College of Science, South Kensington, S.W., 5 p.m.

Timber Trade Lectures, at the London Chamber of Commerce, Oxford Court, Cannon Street, E.C., 6.30 p.m. Mr. Percy A. Wells, "Colour and Figure in Wood applied to Furniture Design."

Announcements intended for insertion in this list must be received at the SOCIETY'S Office not later than the Monday of the week preceding the Meeting.

***For Meetings of the ROYAL SOCIETY OF ARTS, see page 19.**

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

NOTICES.

NEXT WEEK.

MONDAY, DECEMBER 11th, at 8 p.m. (Cantor Lecture.) WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Brown Coal and Lignites." (Lecture III.)

WEDNESDAY, DECEMBER 13th, at 8 p.m. (Ordinary Meeting.) SIR SIDNEY F. HARMER, K.B.E., Sc.D., F.R.S., Director of the British Museum of Natural History, "The Loss of Colour in Objects exposed to Light." THE EARL OF CRAWFORD AND BALCARRES, K.T., P.C., F.S.A., will preside.

FRIDAY, DECEMBER 15th, at 4.30 p.m. (Indian Section.) Commissioner F. de L. BOOTH TUCKER, "The Settlements of Criminal Tribes in India." SIR EDWARD R. HENRY, Bt., G.C.V.O., K.C.B., Inspector-General of Police, Bengal, 1891; Commissioner of Police in the Metropolis, 1903-18, will preside.

FOURTH ORDINARY MEETING.

WEDNESDAY, NOVEMBER 9th, 1922: Admiral of the Fleet SIR HENRY B. JACKSON, G.C.B., K.C.V.O., D.Sc., F.R.S., in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Carmichael, Harry Tucker, Kentucky, U.S.A.
Christie-David, Clement Harold, Colombo.
Johnson, George, Leigh-on-Sea.
Nutt, Ernest S., Sheffield.
Patterson, Thomas Hamilton Hoge, Philadelphia, U.S.A.
Starr, Nathan Comfort, Maryland, U.S.A.
Swift, George, J.P., Pershore, Worcester.
Vardy, Rev. Reuben, Ripon, Yorks.
Varman, Thakur Gopi Nath Sinha, B.A., Barielly, U.P., India.

The following candidates were duly elected Fellows of the Society:—

Aguilar, Ponciano, Guanajuato, Mexico.
Graham, Captain H. A. R., London.
Koder, Samuel Sabattai, Malabar Coast, India.
Maclay, William Walter, M.A., C.E., Lee, Massachusetts, U.S.A.
May, Mrs. Emma Lilian, London.
Prasad, Tewari Balbhadra, M.L.C., Old Cawnpore, India.
Sanders, Cameron Oswald, Derby.
Stephens, Fred S., Calcutta, India.
Van Norden, Warner M., LL.D., New York City, U.S.A.

A paper on "The Hot Wire Microphone and its Applications to Problems of Sound" was read by MAJOR W. S. TUCKER, R.E., D.Sc.

The paper and discussion will be published in the *Journal* of December 29th.

CANTOR LECTURES.

On Monday evening, December 4th, PROFESSOR W. A. BONE, F.R.S., delivered the second lecture of his course on "Brown Coals and Lignites."

The lectures will be published in subsequent numbers of the *Journal.*

DOMINIONS AND COLONIES SECTION.

TUESDAY, DECEMBER 5th, 1922; MR. EDWARD DENT, Vice-President, Court of Directors, British North Borneo Company, in the Chair. A paper on "British North Borneo" was read by MAJOR OWEN RUTTER.

The paper and discussion will be published in a subsequent number of the *Journal.*

REPRINT OF CANTOR LECTURES.

The Cantor Lectures on "The Constituents of Essential Oils" by LIONEL GUY RADCLIFFE, M.Sc.Tech., F.I.C., have been reprinted from the *Journal*, and the pamphlet (price 2*s.*) can be obtained on application to the Secretary, Royal Society of Arts, John Street, Adelphi, W.C. 2.

A full list of the lectures which have been published separately and are still on sale can also be obtained on application,

MANN JUVENILE LECTURES.

Under the Mann Trust a short course of lectures adapted to a juvenile audience will be delivered on Wednesday afternoons, 3rd and 10th January, 1923, at 3 p.m., by Mr. Charles R. Darling, A.R.S.Sc.I., F.I.C., on "The Spectrum, its Colours, Lines, and Invisible Parts, and some of its Industrial Applications." The lectures will be illustrated with experiments.

Special tickets are required for these lectures. A sufficient number to fill the room will be issued to Fellows in the order in which applications are received, and the issue will then be discontinued. Subject to these conditions, each Fellow is entitled to a ticket admitting two children and one adult. Fellows who desire tickets are requested to apply to the Secretary at once.

PROCEEDINGS OF THE SOCIETY.

SECOND ORDINARY MEETING.

WEDNESDAY, NOVEMBER 15TH, 1922.

CAPTAIN W. E. NUTTALL, M.B.E., Chairman of the Technical Section, Paper Makers' Association, in the Chair.

THE CHAIRMAN, in introducing the lecturer, said there were many processes in the manufacture of paper, but he thought the audience would agree with him that the most important was that which went on in the beating engine. He did not think there could be any difference of opinion about that. On the success or failure of that process depended the success or failure of the finished article. One could tell weary stories of dissatisfied customers accusing the poor harassed paper maker of seeking to take too much out of the furnish of his paper, when, as a matter of fact, the only reason was that something had gone wrong with the beating of the paper. Perhaps that was not quite a serious enough statement for the present important occasion, but he was seized with the conviction that there was nothing of so much importance and value to the trade as investigations into the subject of the beating of papermaking fibres.

The Technical Section of the Paper Makers' Association had had to consider into what field it should go in order to carry out researches which would benefit the industry as a whole, and it had deliberately chosen the field of beating, and was going to carry out research in that field. He thought that they were very fortunate and privileged that evening in being assembled to hear a paper from one who had already achieved international fame in that very difficult and involved subject. The more one looked into it the more mysterious it became and the more it bristled with difficulties. Dr. Sigurd Smith had patiently investigated for many years that intricate matter with courage, with originality and with ingenuity which left nothing to be desired. He (the Chairman) thought he was right in saying that the present state of beating was, at all events, in this country, more an art than a science. In making that remark he was not saying anything derogatory to their splendid works managers and workmen, who did the work; but if to that art could be added the certainty which came from a real understanding of what took place in that very important process, then, he thought, something would have been achieved. He ventured to think that Dr. Sigurd Smith was going to make a very important contribution to the knowledge which they possessed at present.

The following paper was read:—

THE ACTION OF THE BEATER IN PAPERMAKING:

WITH SPECIAL REFERENCE TO THE THEORY OF THE FIBRAGE AND ITS APPLICATION TO OLD AND NEW PROBLEMS OF BEATER DESIGN.

BY DR. SIGURD SMITH.

I should like to be permitted, in the first place, to express to your Council my warm appreciation of the honour of being invited to submit to such a distinguished gathering the results of my latest investigations on beaters. Standing before you here in London, my thoughts unconsciously direct themselves to that sphere of the existing knowledge of our subject, for which we are indebted to Great Britain and to British research. Before beginning to relate what we have accomplished in Denmark, I therefore wish to record my gratitude for, and appreciation of, all that we have learnt from Great Britain. I call to mind the many excellent publications of Cross & Bevan, the immense amount of work represented in Clayton Beadle and Stevens' book on "The theory and practice of beating." English technical journals, too, have been of no little value to me, often containing very reliable reports on beater tests and furnishing just such practical data as are necessary to the theorist. Facts form the foundation on which any theoretical structure must rest. In my view, the British are possessed of a special genius for fact and reality, and I

feel secure in building up on the basis of British experience.

My paper is sub-entitled, "The theory of the fibrage and its application to old and new problems in beater design."

The theory of the fibrage was first propounded in my dissertation entitled "Heltojshollaenderen" published in Copenhagen in 1920. This was later translated into German and published under the title of "Die rationelle Theorie des Ganzzeughollaenders."

In these books the presence of fibrages on beater bars was explained, and the logical consequences deduced. Rational mathematical formulæ were evolved for the beating output of a beater, and for the character of the finished stuff. These formulæ are, however, rather unwieldy for use under industrial conditions. Their chief importance extends towards bringing clear thought to bear on the relation between the physical processes which take place in the beater. For use in connection with practical beater trials, handier methods of calculation are desirable.

This evening I propose to describe briefly the so-called fibrage theory, and to demonstrate the application of this theory in practical beater trials as well as its uses in beater design. In conclusion, I should then like to bring to your notice a new and effective type of beater which has been directly evolved out of the theory of the fibrage.

THE FIBRAGE.—Imagine a trough containing stuff mixed with water. If a knife

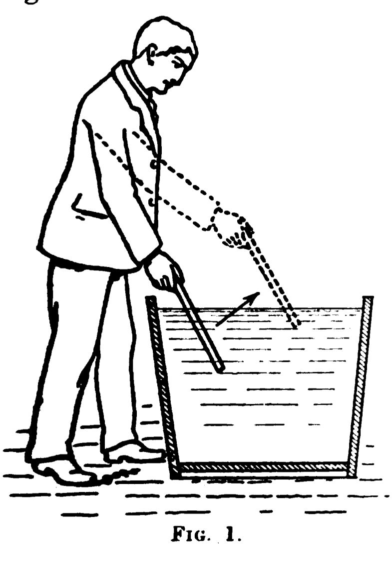

FIG. 1.

is drawn through the stuff, as shown in Fig. 1, fibres will be observed to adhere to the blade of the knife in a transverse film or fibrage. If the knife is moved through the stuff sufficiently quickly, it will be seen that the fibres assume a definite formation, and present a uniform fibrage along the whole length of the blade. This phenomenon is familiar to every papermaker, and is occasionally utilized to examine the length of beaten fibres; for the shorter the stuff is beaten the smaller will be the fibrage.

Experiments have been carried out to determine how the size of the fibrage varies with fibres of different lengths, and with stuffs of different consistencies. For these experiments, instead of using a knife, a rod was employed of square section steel with sharp edges, the rod being seven millimeters square. Fig. 1. shows the method of carrying out the experiments, and the results are shown in Fig. 2. The abscissae

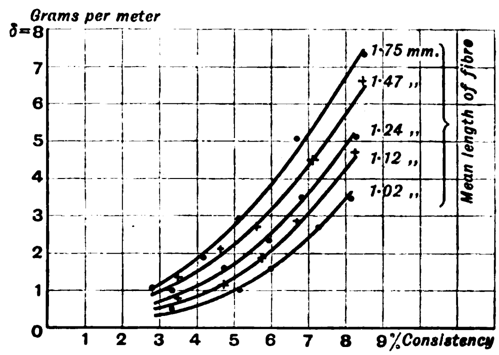

FIG. 2.

represent the consistency of stuff in the trough, and the ordinates represent the number of grams of dry fibre adhering to each meter length of rod. It will be observed, that the fibrage grows extremely rapidly as the consistency increases. This is a remarkable fact which will be referred to again later in explaining certain conditions which obtain in the beater. In Fig. 3, the abscissae indicate the mean length of fibre in millimeters, and the ordinates show the size of the fibrage in grams per meter length of rod. These curves show that the fibrage also grows very rapidly as the length of fibre increases.

Let us now consider the action of the beater roll on the stuff in the beater trough (Plate No. 2, p. 45). The stuff flows slowly towards the roll while the fly bars revolve at a high speed. The forward edges of the bars will, therefore, so to speak, plane or

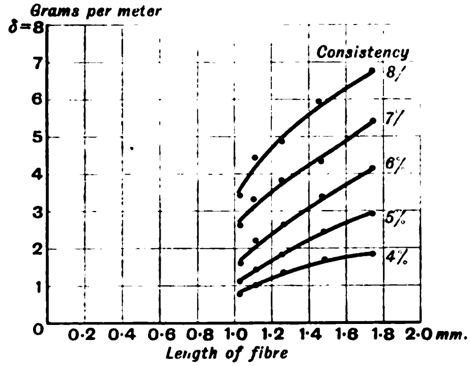

FIG. 3.

scrape off a thin layer of stuff. This thin layer slides, like a wood shaving, radially along the front surface of the bar. If the observer imagines himself to be moving with the bars in Fig. 4, and assuming the

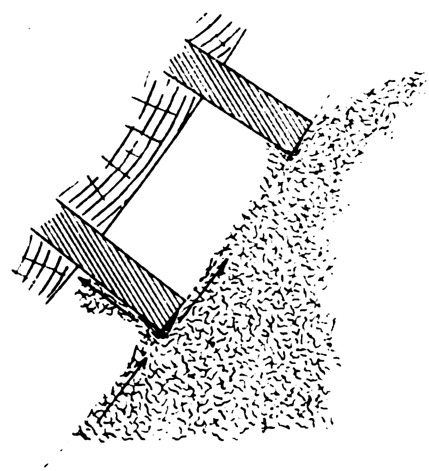

FIG. 4.

arrow to denote the apparent velocity of the stuff relative to the bars, then it will be seen that the stuff stream will be cleft by the forward edges of the bars, part of the stuff moving along the end surface of the bar (*i.e.*, tangentially) and part along the front surface of the bar (*i.e.*, radially). As a result, a number of fibres will adhere to the forward bar edges in the form of a fibrage in exactly the same way as in the experiments with the square steel rod. This fibrage is too small to be shown clearly in Plate No. 2. When the bar edge carrying its fibrage reaches the bedplate, part of these fibres are cut against the edges of the bedplate bars and part are abraded and squeezed against the surface of the bars. The cutting action causes the fibres to be shortened to the required length, while the abrasion and squeezing partially fibrillates and partially softens and hydrates them.

The doubt might possibly suggest itself as to whether the fibrage gathered on the fly bar edge corresponds exactly to that formed in the square rod experiment, and whether the same rules hold for the behaviour of each. It is therefore desirable to examine to what extent the results of the rod experiment correspond with practical experience of the behaviour of fly bar fibrages.

It is known that the fly bar fibrage diminishes in size as the consistency decreases, just as was found in the case of the rod. This is shown by Green's tests (A. B. Green : Management of the Beater Room. *Paper*, 1917, No. 23). At a thin consistency (3·6%) Green observed that, under the same roll pressure, the clearance between roll and bedplate was less than at a higher consistency (about 5%); that is to say, the fibrages were smaller.

The knowledge that the size of the fibrage varies with the consistency of furnish, helps us also to understand why stuff beaten at thick consistencies becomes "wet." If the size of the fibrage increases so rapidly with the consistency, the treatment of the stuff between the roll and bedplate will be far less harsh as the consistency increases, for the fibrage then acts as a cushion between the bars, and the latter only produce a relatively slight cutting effect.

Practical experience with beaters also shows that the size of the fibrage diminishes as the shortening of the fibre progresses. Thus it is well known that the cutting action of the roll ceases after the stuff has been treated for a certain period, and is only resumed when the roll is let down further. (A good illustration of this may be found in the curves published by Clayton Beadle, *Chapters on Papermaking*, V., p. 151.) The explanation is that after beating for some time, the fibrage becomes so attenuated that no more cutting can take place until the clearance between roll and bedplate has been reduced accordingly.

It will be seen from the foregoing, that practical experience agrees in all essentials with what one would expect according to the theory of the fibrage and the rod experiments. This certainly affords a good support for the theory.

THE CONDITION GOVERNING THE SPEED OF CIRCULATION OF THE STUFF. (Stuff Travel Condition).—Proceeding further, it will now be assumed that the size of the fibrages on the fly bars has a deciding influence on the output of a beater and on the quality of the finished sheet. It will be shown how this assumption leads to the well-known rule that chemical wood pulp should be beaten at thick consistencies and at a rapid rate of circulation. On these lines a basis will be obtained for calculating, in connection with any given beater, the relative importance of consistency and speed of circulation.

Our first task is to determine the conditions which conduce to maximum formation of fibrage on the edges of the fly bars.

Fig. 2 shows the size of the largest fibrage which it is possible for a bar edge to collect under given conditions. Assuming a mean length of fibre of 1.75 mm., then we may say that the top curve in Fig. 2 indicates the size of the largest fibrage possible at various consistencies. It is evident that in order for such fibrage to collect on the fly bar, the latter during its passage must encounter at least as many fibres as it is expected to collect: in fact, probably far more, as a considerable number of fibres are likely to escape retention by the edge of the fly bar. It is then necessary to ascertain how much stuff is planed off by each bar, or in other words how much stuff enters the space between each two consecutive fly bars. (This quantity of stuff will be called the "cell content.")

For any given consistency, therefore, the condition for the formation of the maximum sized fibrage on the edges of the fly bars, is *that the cell shall contain a larger quantity of stuff than would be required to form this fibrage.* This condition is known as *the Stuff Travel Condition.*

The following example may be taken in illustration :—

Assume that the cross sectional area of the stream of stuff in the beater trough, measured on the side of the trough opposite to the roll, is 49.5 sq. decimeters. The speed of travel of the stuff is taken to be approximately constant throughout this cross section at one meter per 11 seconds. The stuff will, therefore, travel round the trough at the rate of $\frac{10 \times 49.5}{11} = 45$ liters per second.

If the roll is running at 150 revs. per minute and there are 90 fly bars, then the number of cells which take part every second in transporting the stuff is given by: $\frac{150 \times 90}{60} = 225$. Each cell will therefore contain $\frac{45}{225} = 0.2$ liters of stuff. If the length of the bars is 1 meter, each meter length of cell will thus contain 0.2 liters of stuff.

On the assumption that the consistency of the stuff is 6%, then each cell will contain $\frac{6 \times 200}{100} = 12$ grams of fibre.

From Fig. 2 it will be seen that the maximum amount of fibre retained per meter length of bar edge from 6% stuff is 4 grams.

If the fly bar reaches the bedplate with 4 grams of fibre adhering to its edge, then it is this quality of fibre that must have been supplied from the contents of the cell. The latter was shown to contain 12 grams of fibre. It is, therefore, clear that over three times as much fibre must have passed by the bar edge as should have been retained on the latter, and the Stuff Travel Condition is thus fulfilled in this case.

This Stuff Travel Condition has been tested in a large number of beating trials, partly where the beater was operating at an adequate speed of circulation and partly where the circulation was too slow for the beater to give a satisfactory output. On the basis of the values given by the top curve in Fig. 2 it was found that in order to secure the best beating effect, the cell content required to be 2½ to 3 times greater than the maximum fibrage.

Fig. 2 shows the following values :—

Consistency	3%	4%	5%	6%	7%	8%
Maximum Fibrage	1.2	1.9	2.8	3.9	5.3	6.8
$\frac{\text{Maximum Fibrage}}{\text{consistency}}$	0.4	0.48	0.56	0.65	0.75	0.85

Seeing that the maximum fibrage increases much more rapidly than the consistency, it, therefore, follows from the Travel Condition, that *increasing the consistency in a beater necessitates more rapid circulation*, if it is desired to keep on working under the most favourable conditions. In consequence of the thicker consistency and the larger fibrages which this entails, the fibres will be subjected to milder treat-

ment. In the case of chemical wood pulp, the result will be a stronger sheet and shorter beating time.

Taking for granted that chemical wood pulp usually requires gentle treatment in the beater, the above conditions prove theoretically the truth of the practical rule that chemical pulp should be beaten at a high consistency and at a high rate of travel in the beater.

A long series of trials has shown that this holds in the case of chemical wood pulp, but similar trials show that it does not apply in the same way in the case of strong rag fibres (linen, cotton). The trials were carried out in a beater operated in conjunction with three other beaters. It was anticipated that the beating time of the test beater would be 7/10ths that of the other beaters. The relative beating effects were compared by comparing the respective finished sheets as regards breaking length, stretch and folding. The sheet produced from the three ordinary beaters was taken as a standard for the purpose of ascertaining the beating effect of the test beater.

In the first 23 trials carried out with the test beater, the furnish was too thick to enable the proper speed of circulation to be obtained.

As was expected, it was found in the trials on rags that the stuff treated in the test beater was ready in 7/10ths of the time taken by the other beaters without any sacrifice in the quality of the sheet. On the other hand it proved impossible to obtain the desired quality of sheet from chemical wood pulp beaten under similar conditions. The consistency was then slightly reduced so as to increase the speed of circulation to the point of fulfilling the Travel Condition; and further trials produced the required quality of sheet in the beating time laid down.

This experience clearly shows the importance attaching to the fulfilment of the Travel Condition in beating chemical wood pulp. It emphasises, moreover, the curious difference which exists in this respect between the beating of rags and of chemical wood pulp. The wood fibre has thinner walls and is less resistant to mechanical treatment than rag, so that in beating wood it is desirable to secure the largest possible fibrage on the fly bars in order to mellow the beating action. Rag fibres being comparatively more resistant to tearing and cutting and thicker-walled, can be worked in a thinner layer without being destroyed. All this corresponds with practical mill experience. Chemical pulp requires to be beaten at a thick consistency with rapid circulation, while rags do not. In fact, many rag mills prefer to use old flat-bottomed hollanders, which will not handle stuff thicker than 4% and give very slow circulation. In such beaters the fibrage must necessarily be very small.

THE CUTTING ACTION.—Many experts are inclined to hold that no cutting takes place unless the roll is so hard down that there is direct contact between the roll and bedplate bars, *i.e.*, that all the fibres are severed. This view is, however, not correct. Even if the roll is only sufficiently hard down to rest on the fibrages, there will be a certain amount of cutting action. If the combined effect of a roll and bedplate bar be compared to that of a pair of scissors it can be shown by the following experiment that even when the scissor blades are not pressed hard together, a bundle of fibres clamped between the blades will be partially severed. Bundles of hackled hemp were wound round the stationary and revolving knives of a lawn mower—(Fig. 5)—the

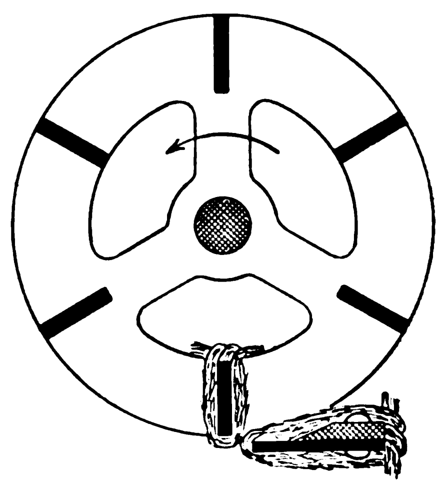

FIG. 5.

knives were blunt and were adjusted to give a working clearance of less than 1 mm. The mower was only run far enough for the two bundles of fibres to meet one another once, and it was then found that a considerable number of hemp fibres were cut, the major proportion consisting of those situated nearest to the knives.

I have referred in various places to gentle beating of the fibre. Experiments have been carried out to determine what percentage of the fibre which comprises the fibrage is cut when the fly bars pass over the bedplates. Micro-measurements of the mean length of fibre enable this percentage to be calculated, on the sole assumption that the fibrage on the edge of a fly bar is the same size as that formed under similar conditions (of consistency and length of fibre) on the edge of the square rod (referred to above). It has already been shown that this assumption is very probably true. A calculation, which I have omitted from the present paper, indicates that at the commencement of beating 1.2%, and at the conclusion of beating 1.7%, of the fibre contained in the fibrage is cut in passing over the bedplate.

CIRCULATION. — As already explained, thick furnish and rapid circulation are essential to the perfect beating of chemical wood pulps. It is not easy to make a thick furnish circulate rapidly, but a great deal can be effected by devoting attention to the design and construction of every part of the trough, viz., bottom, walls, backfall, hood and the approach to the roll (front rise). The requirements in this connection not being generally known are, therefore, frequently neglected. As a result, either too much power is consumed or else the circulation is too slow and the beating bad. The whole of the factors involved have been investigated, but time will only permit me to describe the main results of my investigations.

In the ordinary hollander type of beater (without a propeller or other special circulating device) the circulation is effected by the roll, which lifts the stuff like a bucket wheel and rejects it at such a speed that it is thrown over the backfall. The stuff then flows round to the roll again under the influence of gravity. The circulation may, therefore, be regarded as being determined by two different factors, viz., the transporting capacity of the trough and that of the roll. If the speed of circulation remains constant, the amount of stuff transported by the roll must be exactly equivalent to the rate of flow round the trough. Let us consider both these factors separately.

TRANSPORTING CAPACITY OF THE TROUGH.—As with flowing liquids, one might expect that a high head behind the backfall would suffice to import to the stuff sufficient energy to make it circulate. The peculiar nature of stuff, however, intermediate between solid and liquid, nullifies this expectation. If the bottom of the trough is horizontal from backfall to bedplate, then unless the furnish is extremely thin, there will only be a very sluggish movement in the top layer of stuff and no movement at all at the bottom. Exactly as an inclined plane is necessary for a solid body to slide under the influence of gravity, so also must the bottom of the beater be inclined in order to circulate thicker furnishes.

The work done by gravity while the stuff travels from the top of the backfall back to the roll, is partly absorbed in overcoming the internal friction of the stuff and the friction of the stuff against the walls of the trough, and partly in imparting to the stuff the velocity which it possesses on approaching the roll. This latter amount of work is so small (about 1%) that it may be neglected here. The preponderating amount of work is done in overcoming internal friction at the curved portions of the trough. Now it has been shown elsewhere* that the internal friction in the stuff is independent of the velocity of its internal motion. It therefore follows that the resistance to circulation will remain constant irrespective of the speed of circulation, so long as the consistency remains unaltered. The transporting capacity of the trough is, therefore, the same whether the circulation be slow or rapid. The head measured from the surface of the stuff at the top of the backfall to the surface at the front side of the roll will only alter very slightly, however much the speed of circulation may vary. On the other hand, if the furnish is thickened, the surface of the stuff will become more inclined. The trough, therefore, does not exercise a determining influence on speed of circulation, because so long as the trough bottom slopes sufficiently for the given thickness of furnish, the trough will always be able to transport as much stuff as the roll will deliver over the backfall. Nevertheless, with a thick furnish the trough will cause the level of the stuff to be low at the front side of the roll, while with a thin furnish it will be higher.

THE TRANSPORTING CAPACITY OF THE ROLL.—The transporting capacity of the

* *Die rationelle Theorie des Ganzzenghollaenders*

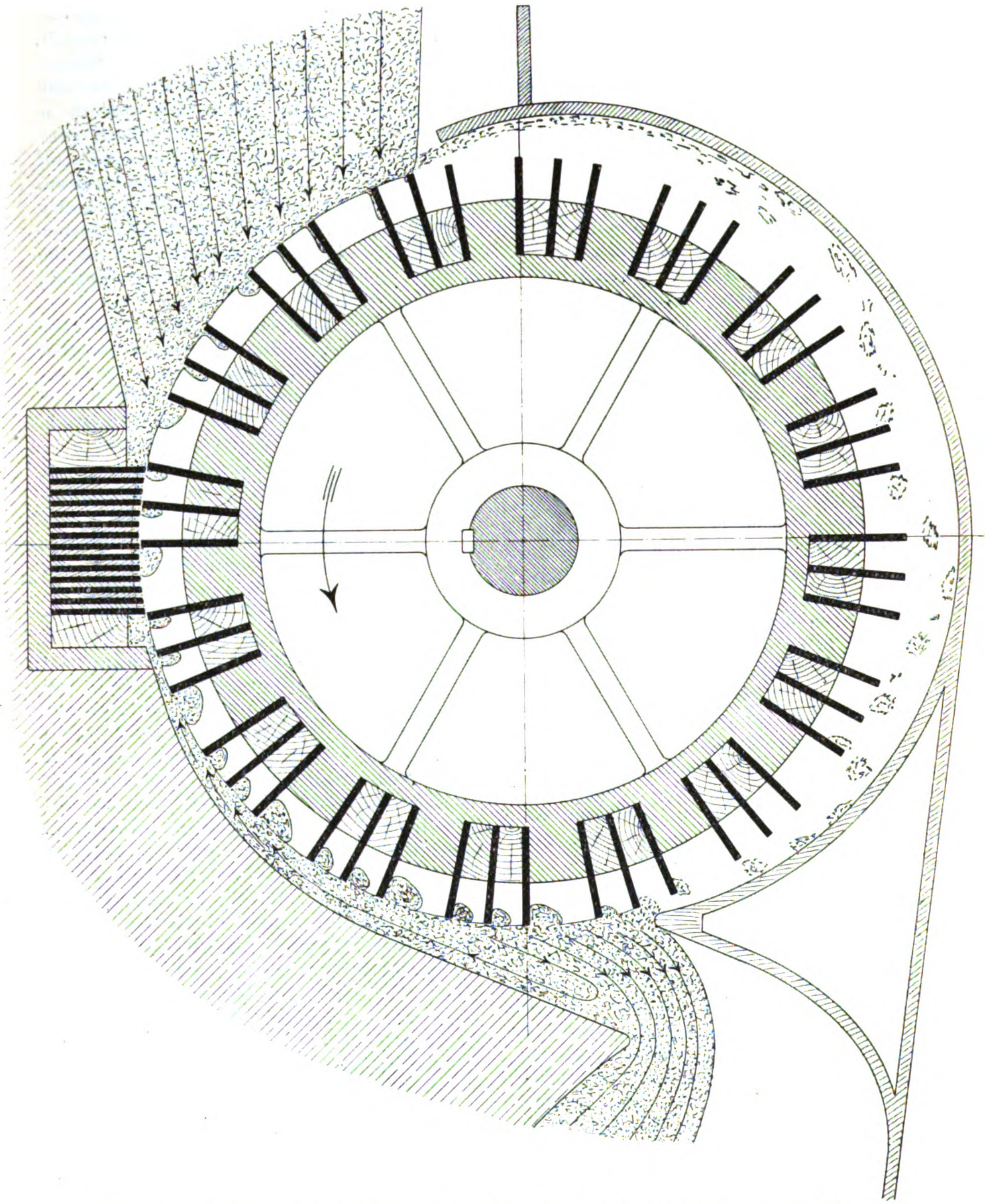

Plate 1.—Incorrect Spacing of Flybars.. Incorrect shape of Front Surface of Backfall.
(The roll transports the same quantity of stuff as the Roll shown in Plate 2.)

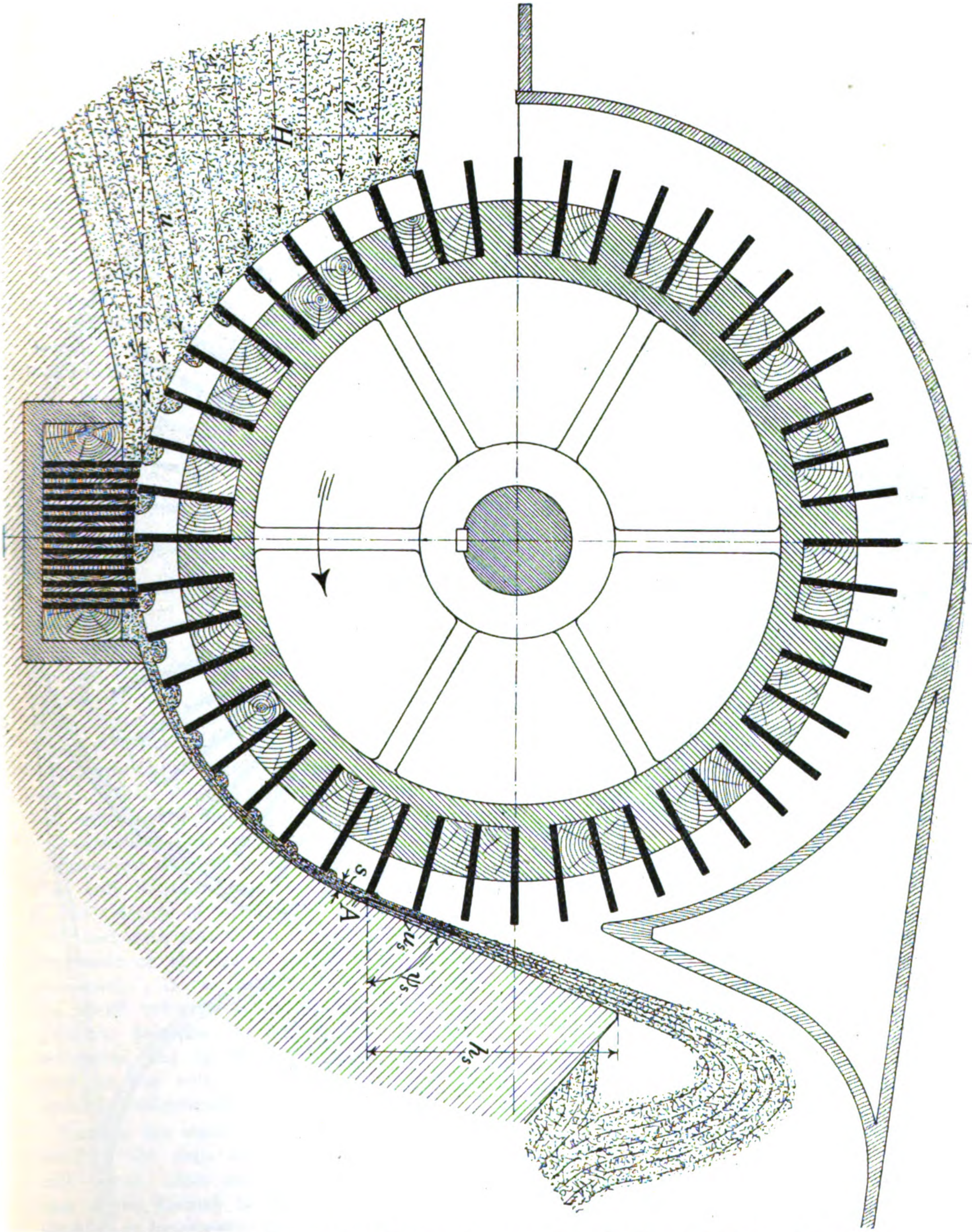

PLATE 2.—Correct Spacing of Flybars. Correct shape for Front Surface of Backfall.
(The Cell Content is sufficiently large to carry away the stuff in the Clearance Space.)

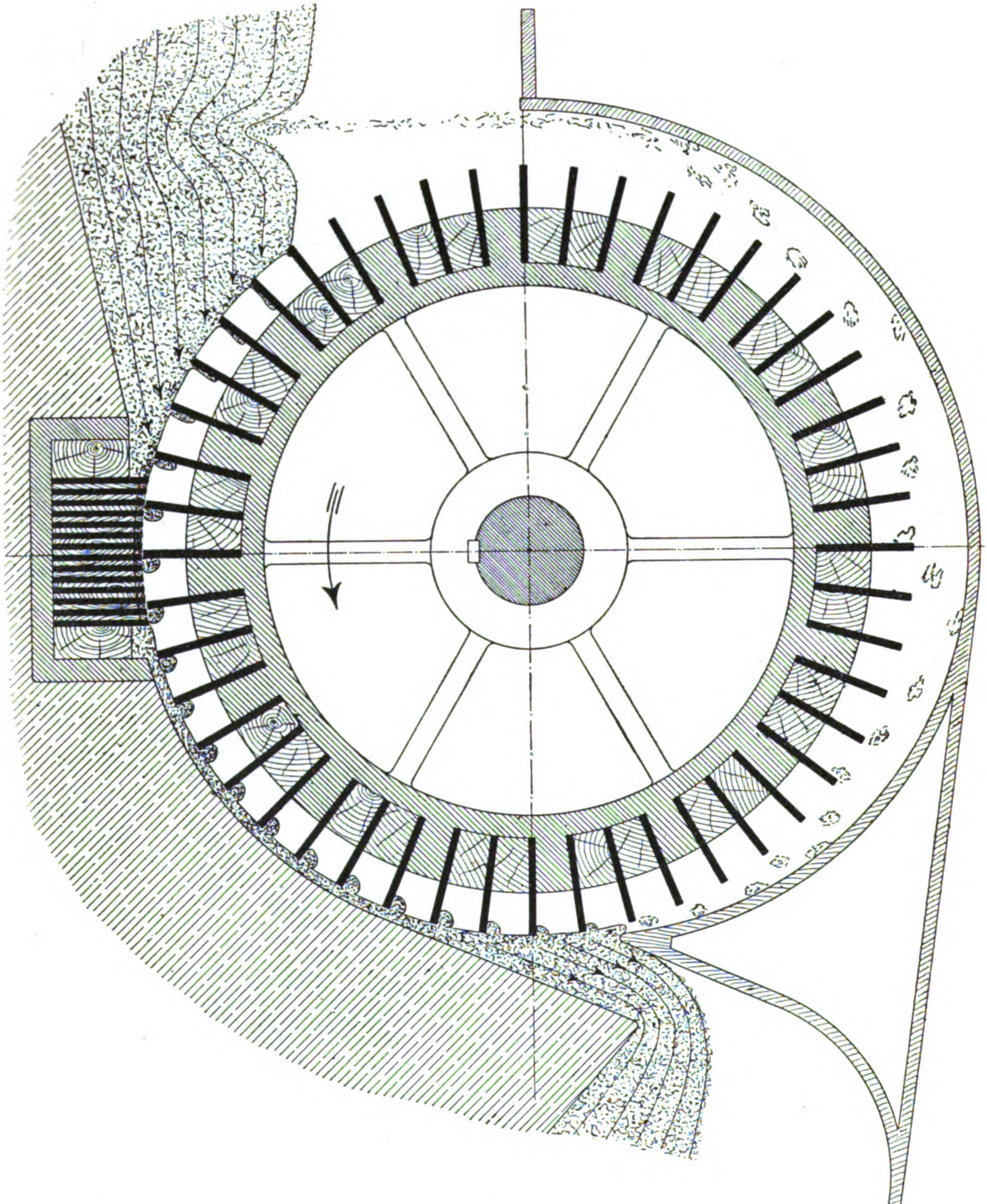

PLATE 3.—Correct Spacing of Flybars. Correct Shape for Front Surface of Backfall.
(The Cell Content is too small to enable the Stuff in the Clearance Space to be carried away.)

trough may be regarded as practically unlimited, if the bottom is sufficiently sloped to correspond with the consistency of the furnish. The same remark applies to the roll if it be regarded in the light of a bucket wheel. The transporting capacity of the roll is so far unlimited that the cells will be able to hold far more stuff than can be required for the formation of fibrages. In practice it never occurs that the cells are anywhere near filled with stuff. Nevertheless, the stuff always assumes a moderately slow speed of circulation, and even if the trough bottom is properly inclined, and the roll suitably constructed, it may occur that the circulation is too s ow. The reason for this may be looked for at two critical points, viz. :—

1. At the entry of the stuff into the cells ;
2. At the ejection of the stuff from the cells ;

and we shall proceed to examine these two features.

From Plate 2, it will be observed how the forward edges of the roll bars cut or plane off a layer or shaving from the approaching stuff. This layer is forced radially along the forward surface of the fly bar until its motion ceases owing to friction on the surface of the bar and centrifugal force. It will also be seen from Plate 2, how the stuff which enters the cells, gradually forms a roll, sausage or eddy, which increases in size as each fly bar approaches the bedplate. It is easy to appreciate the conditions which govern the amount of stuff contained in the cells. The cell content increases with increase in the depth of stuff H in front of the roll, and with the width of the ce.l, but it decreases as the speed of the fly bars is increased. It is incorrect to say that the stuff velocity u determines the cell content, because in the ordinary open hollander, the speed of approach of the stuff to the roll, other conditions being equal, is determined by the cell content.

Even if the inlet conditions for the stuff entering the cells are favourable, it may still occur that the circulation may be bad if the furnish is too thick, or if the backfall is incorrectly designed.

Plate No. 1 shows an incorrect backfall design. The front surface recedes considerably from the roll so that a large space or backfall pocket is produced.. As the roll revolves, the friction of the fly bars and of the stuff in the cells will be insufficient to accelerate the stuff in the backfall pocket enough for it to be ejected at a high speed over the crown of the backfall. Consequently, the pocket will be continuously filled with stuff, of which a portion will be carried over to the front side of the roll, or, in other words, the roll will "spit." It will be shown later that this "spitting" may exercise a very detrimental effect on the circulation. Plate No. 1 indicates how the detrimental effect may be avoided or at least mitigated, by extending the hood round to the front side of the roll so as properly to direct the spitting.

In Plate No. 2, the front surface of the backfall is correctly shown concentric with the roll, and with a fairly small clearance between roll and backfall. Consequently, the friction of the fly bars and of the stuff in the cells is sufficient to drag along the small quantity of stuff in the clearance space and to accelerate it so that stuff can emerge from the cells into the clearance space ; and the entire mass of stuff will be ejected over the crown of the backfall at a high speed. The roll will, therefore, not spit. Not only will this result in a considerable saving of power, but it will be much easier to attain the proper rate of travel in the beater. The correct width of clearance can be calculated, but time will not permit me to enter into constructional details of this kind.

If the beater is furnished too thick the head of stuff in front of the roll wil be too low. (Plate No. 3.) The cell content will, therefore, be too small and the cells will not furnish sufficient stuff for the proper formation of fibrages. This case is illustrated in Plate 3, where it will be seen that the cells do not contain sufficient stuff. These small quantities of stuff in the cells are unable, moreover, to drag round the stuff contained in the clearance space between roll and backfall. No stuff will emerge from the cells into the clearance space, and each cell will only commence to empty as it approaches the crown of the backfall. The backfall pocket fills with stuff, the roll spits and the whole condition reacts detrimentally on power consumption and retards circulation.

"Spitting."—The retarding effect of spitting on circulation can best be seen from the experimental results given in

Table I. In a beater working with 5.1% consistency, the stuff was ejected in a proper manner over the crown of the backfall, and there was very little spitting (only 2 liters per second). The circulation in the beater was 67 liters per second,

TABLE I.

Consistency.	Circulation in liters per sec.	Spitting in liters per second.	Total quantity transported by the roll per second.
5.1%	67	approx. 2	approx. 70 liters.
5.25%	23	10–15	approx. 35 liters.
5.85%	12	10-15	approx. 25 liters.

and the roll, therefore, handled in all roughly 70 liters of stuff per second, which was sufficient for the formation of the fibrages. On the consistency then being increased to 5.25%, the depth of stuff in front of the roll diminished slightly, but caused the cell content to decrease so much as to render it impossible for the stuff in the clearance space to be carried away, and heavy spitting took place (10 to 15 liters per second). This spitting produced so great a resistance to the flow of stuff in the trough as to reduce it to 23 liters per second, the roll thus handling in all only 35 liters of stuff per second, a quantity quite insufficient for the proper formation of fibrages. At the still higher consistency of 5.85%, the quantity of stuff transported by the roll was further diminished owing to the lower depth of stuff in front of the roll, and the beating conditions deteriorated still further.

THE BEDPLATE.—It follows from what has been said that the action of the bedplate consists largely in abrading the fibrages carried by the edges of the fly bars. Thus it is useless to increase the number of bedplate bars beyond a certain limit. The width of the bedplate should not be greater than is necessary under the given roll pressure to abrade the fibrages. The view is often held, especially by theorists, that the output of a beater increases with the width of the bedplate or with the number of bedplate bars. This view is opposed by those occupied with beating in the mill, because experience shows that, for example, doubling the width of the bedplate does not increase the output at all. Experiments of this kind have been carried out by Messrs. Ward and Greenhalgh, whose results were communicated to a meeting in Manchester in December, 1921, of the Technical Section of the British Paper Makers' Association. Both these gentlemen found that a considerable alteration in the width of the bedplate produced no effect on the quality of the sheet or on the beating time. Beater designs embodying a large number of bedplate bars, in some cases even extending up to the crown of the backfall, have not proved satisfactory: and the general practice is still to use the old well-known type of bedplate of moderate width and a moderate number of bars. Practical men have long ago discovered by experience the shape, thickness and number of bedplate bars necessary to abrade the fibrages, although it has not been understood why increasing the width of the bedplate should be useless. There is only one way in which the output of the beater can be increased by increasing the number of bedplate bars. To effect this, provision must be made for the formation of fresh fibrages on the edges of the fly bars at one or more spots between the bedplate bars. Experiments formerly made in this direction, in which it was endeavoured to introduce fresh stuff between the bedplate bars, failed. I shall later describe a new design which has successfully overcome this difficulty.

THE OUTPUT OF THE BEATER.—It is now easy to lay down a basis for calculating the output of a beater. It is clear that the output must be proportional to the aggregate length of fibrage carried over the bedplate per minute. The output, therefore, increases in direct proportion with the number of fly bars and their length, and with the number of revolutions per minute of the roll. The product of these three factors, termed the "roll value," affords a measure of the output capacity of the beater. The number of bedplate bars naturally does not enter into an expression for the output capacity of the beater, but it is assumed that there are sufficient bedplate bars to abrade the fibrages. In connection with beating chemical wood pulp it must, in addition, be assumed that the beater is so designed as to permit each fly bar to collect the maximum sized fibrage possible. This involves not only

rapid circulation but also the necessity of spacing the fly bars sufficiently widely apart. This latter requirement is frequently neglected especially where the bars are fitted in clumps of 3 or 4, giving one large gap or cell followed by two or three smaller ones and so on. If the circulation is just sufficient to furnish an adequate fibrage on the bar following a wide cell, then a small cell will contain too little stuff for the formation of a fibrage. Such a beater, therefore, would not possess as much output capacity as might be expected, unless extra rapid circulation can be secured. In beating rags, on the other hand, the Travel Condition need not be fulfilled.

It would be possible to increase the output capacity of a roll by modifying the bedplate if one were able to provide the edge of the fly bars with fresh fibrages as soon as the original ones are abraded. The second fibrage would be beaten against a second bedplate, and so on. The output capacity of the roll would be increased two-fold, three-fold or multifold, by beating in this way with two, three, or a correspondingly larger number of bedplates.

Power Consumption.—We shall now proceed to consider the power consumption of a beater and to examine what proportion is utilized effectively and what proportion wasted.

Regarded as a machine the beater is extremely uneconomical. Barely half the power consumed is utilized in beating: in fact frequently only 1/3 to 1/5 of the total power consumption is absorbed in beating between the roll and the bedplate. The remaining power may be looked upon chiefly as wasted on (1) friction losses in the shaft bearings; (2) losses due to the whipping of the fly bars partly against the stuff which enters the cells and partly against the stuff which is carried and eddied between the roll and the hood; (3) losses resulting from the friction of the stuff revolving with the roll, against the stuff in the trough and in the clearance space between roll and backfall. The loss of power due to these causes is approximate y equal to the power consumption of the beater when the roll is raised, that is to say, when the roll is only whipping the stuff without touching the bedplate.

The power consumed in whipping contributes to a very slight extent towards the softening (hydration) of the stuff. Experiments have shown that it is much more expensive to achieve a given degree of wetness by whipping than by beating the stuff between the roll and the bedplate. All the investigations dealt with in this paper refer primarily to conditions in which actual beating takes place between the roll and the bedplate as for instance in mills making better class and fine papers. The power that is not consumed in beating between the roll and the bedplate may, therefore, be regarded as a loss which should be minimized to the greatest possible extent. (In mills making wrappings, news and similar sheets which are run over the machine at high speeds, freer stuff is required and for such sheets the wetness produced by whipping alone may assume a certain amount of importance).

If the beater is direct-motor driven the total power consumption can be measured when the roll is actually beating. If one subtracts from this figure the power consumed when the roll is raised, the difference will give the power absorbed in the actual beating between the roll and bedplate or in other words, the effective power consumption. A large number of measurements of this kind have been carried out, from which may be seen what per centage of the total power consumption can, as a rule, be termed effective.

Table II.—Beating Chemical Wood Pulp.

		Mean of tests	Consistency	Percentage of power used effectively.
Hoffsummer Beater	Author's tests	11	6%	43%
Ordinary Beater	Author's tests	4	6%	35%
Arnold Rehn's tests		7	5·73%	31%
Kirchner*		1	5·23%	31%
Kirchner*		1	6·10%	19%
Average	..			32%

* Wochenblatt fuer Papierfabrikation, 1918, p. 1022, tests Nos. I. and II.

TABLE III.—BEATING RAGS.

		Mean of	Consistency	Percentage of power used effectively.
Hoffsummer Beater	Author's tests	tests 7		50%
Ordinary Beater		5	6·1	35%
Arnold Rehn's Tests		4	5.5%	42%
Kirchner*		1	5.0%	73%
		1	5.77%	56%
		Average	..	51%

* Id. tests Nos. III. and IV.

From Tables II. and III., it will be observed that in beating chemical wood pulp only 1/3 of the total power consumption can be regarded as effective, whereas in beating rags ½ is effective. Similar views have been expressed by Professor Pfarr, who maintains that in the ordinary hollander 40% of the power is wasted. Arnold Rehn has also recorded that the power consumed in circulating the stuff frequently amounts to more than 50% of the total power consumption of the beater. At the annual meeting in 1921, of the Canadian Pulp and Paper Association, Mr. Campbell expressed the same opinion, saying, "Whether the stock is wanted long or short, slow or free, the beater can produce it. Inefficiently, it is true, but if properly handled it does produce the desired product. This is unquestioned. That the beater is inefficient is almost equally unquestioned."

Whatever kind of beater is employed, it is probable that the energy expended on the actual work of beating each hundredweight of dry stuff will be the same, to produce the same quality of finished sheet. Every investigation points to the conclusion that the energy absorbed in the actual beating is the same per hundredweight of stuff, irrespective of whether the beater is run for a long time at a low horse power consumption or whether the beating is effected quickly with high horse power consumption, always provided that the Travel Condition is fulfilled and the bedplate is not entirely wrongly designed. It seems natural that the amount of energy consumed in a given beating process should, under these conditions, be quite independent of the beating tackle and of the type of beater employed. In trying to improve the efficiency of the beater no saving is to be looked for in the energy consumed in the actual work of beating between the roll and the bedplate. Economy should be sought in diminishing the losses due to whipping and friction. Any saving in power must be effected either by reducing the ineffective power consumption, or by increasing the effective power consumption and so increasing the output, or by a combination of these two methods.

THE DUPLEX BEATER.—I will now describe a new type of beater, the design of which is based on the considerations already discussed, and I will explain the advantages which this beater possesses.

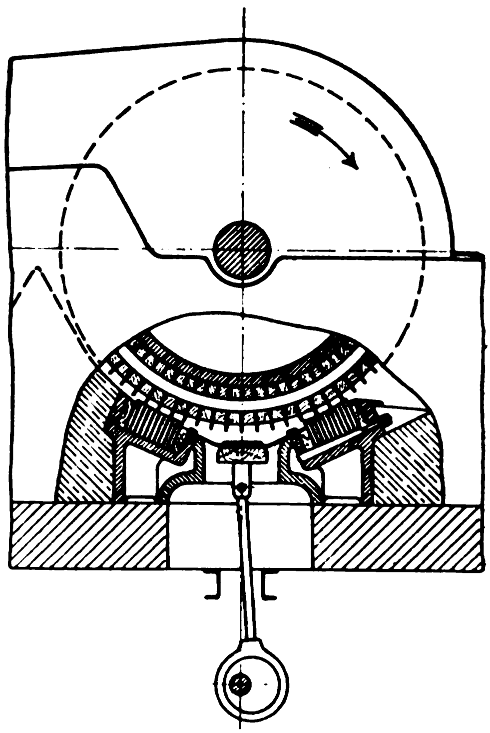

FIG. 6.

Figs. 6 and 7 represent one form of this beater, Fig. 7 being an enlargement of a portion of Fig. 6. The beater is provided with two bedplates located under the roll and separated from one another by a wide gap or chamber. While the fly bars are passing over this gap, they gather on their forward edges a fresh fibrage which is abraded against the second bedplate. Provision is made for replacing both bedplates by a single bedplate to be located

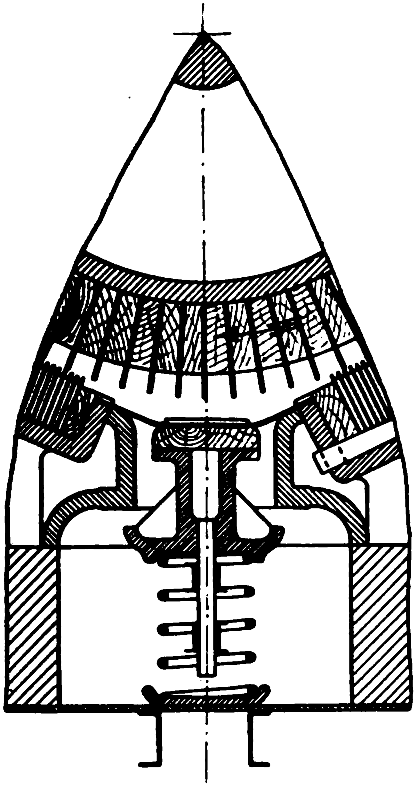

FIG. 7.

under the centre of the roll for experimental purposes. Numerous trials have confirmed that with the two bedplates in use, the beating can be carried out in half the time required with a single bedplate to produce a sheet of the same strength and appearance. It follows that the beating effect of the second bedplate is quantitatively and qualitatively equivalent to that of the first.

For the purpose of forming a fresh fibrage on the fly bars. various devices may be used which all have the object of imparting a radial motion to the stuff transversely across the edges of the fly bars. This motion enables the fly bars to pick up a portion of the passing fibrés in such a way as to form a fibrage. Figs. 6 and 7 show the design originally employed. The radial motion of the stuff is produced by the oscillation of a rubber membrane, which forms the bottom of the chamber between the bedplates. It is actuated downwardly by an eccentric and rod (Fig. 6) and upwardly by springs (Fig. 7).

Later trials have shown that this complicated construction is not always necessary. A fibrage can, under some conditions, be produced by simpler means so long as a uniform radial motion of the stuff is secured. The simplest method of achieving this is to make the bottom of the chamber between the two bedplates lower than the top of the packing between the bedplate bars (Fig. 8). The bottom of

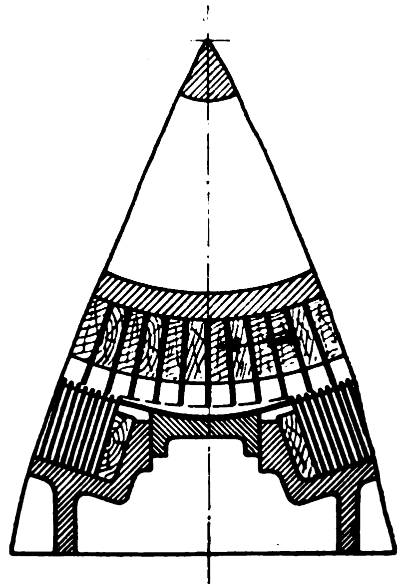

FIG. 8.

the chamber then serves as a guiding sur : for the stuff carried along by the roll notches. Under the influence of the centrifugal force, this stuff is flung against the bottom, slides along the latter in the direction of motion of the fly bars, and finally re-enters the cells to form a fibrage. Beating thus re-commences *de novo* on the second bedplate.

Beaters built on this principle are called Duplex Beaters, because they beat on two bedplates and it will be seen that the use of the duplex arrangement doubles the beating effect of a given beater roll and, therefore, following our previous argument, results in an important saving of power.

With the aid of an example, we will now estimate the saving of power effected by the Duplex Beater, when treating rags and chemical wood pulp, respectively.

1. RAGS.—It will be assumed that a beater with a single bedplate and a furnish of 200 kilos takes 40 h.p. with a beating time of 6 hours. It has previously been shown that only half this power, *i.e.*, 20 h.p., is consumed in the actual beating while the

remaining 20 h.p. are absorbed by the rotation of the roll in the stuff.

A Duplex Beater of the same size will only require 3 hours for beating, but will absorb 2 by 20 = 40 h.p. for the actual beating work.

In beating 200 kilos of rag in the *single bedplate beater* the energy consumption is therefore made up as follows :—

For actual beating 6 × 20=	120 h.p. hours
For revolving the roll in the stuff, 6 × 20 =	120 h.p. hours
Output 200 kilos in 6 hours. Energy consumed.	240 h.p. hours

In beating 200 kilos of rags in the *Duplex Beater* the energy consumption is made up as follows :—

For actual beating 3 × 40 =	120 h.p. hours
For revolving the roll in the stuff, 3 × 20 =	60 h.p. hours
Output 200 kilos in 3 hours. Energy consumed	180 h.p. hours

The Duplex Beater, therefore, gives double the output of the ordinary beater and at the same time saves 25% *in power when handling rags.*

(2) Chemical Wood Pulp.—It will be assumed that the same beater requires 30 h.p. to beat chemical wood pulp in four hours. It has previously been shown that ⅔ of this power, i.e. 20 H.P., are lost in beating chemical wood pulp, only 10 H.P. remaining available for the actual work of beating. A Duplex beater of the same size will only take two hours to produce the same effect but will use 2 × 10 = 20 h.p. for the actual beating.

In beating 200 kilograms of chemical wood pulp in the *single bedplate beater* the energy consumption is therefore made up as follows :—

For actual beating 4 × 10 =	40 h.p. hours.
For revolving the roll in the stuff, 4 × 20 =	80 h.p. hrs.
Output 200 kilos in 4 hours. Energy consumed.	120 h.p. hrs.

In beating 200 kilos of chemical wood pulp in the Duplex Beater the energy consumption is made up as follows :—

For actual beating 2 × 20 =	40 h.p. hrs.
For revolving the roll in the stuff 2 × 20 =	40 h.p. hrs.
Output 200 kilos in 2 hours. Energy consumption	80 h.p. hrs.

The Duplex Beater, therefore, gives double the output of an ordinary beater and at the same time saves 33% *in power when handling chemical wood pulp.*

The numerical examples just shown are of general application and are based on the numerous measurements of the distribution of power consumption in the beater, which have already been referred to. In point of fact the Duplex Beater will under certain conditions effect a saving of up to 40% in the power consumption as measured at the beater pulley.

You will readily understand that the extensive theoretical work which forms the basis of this lecture has been developed from a very large collection of experimental data. The theoretical investigations extended over a period of 5½ years during which time numerous experiments of various descriptions have been carried out. Unfortunately it is necessary to carry out beater experiments in the mill and not in the laboratory. They interfere considerably with the work of the mill and call for a good deal of interest and attentive care on the part of the management. Technological research is therefore indebted to no small extent to the men who have been at pains to interest themselves in the experimental work necessary to such a fundamental treatment of the problem. In this connection I would specially mention the name of my friend and colleague, Mr. Godske Nielsen, director of the Silkeborg Paper mill, on whose initiative the beating problem has been subjected to such thorough investigation.

During the years of experiment I have enjoyed the assistance of a changing staff of engineers and it would not have been possible to carry out these investigations in Denmark had there not been available a staff of engineers thoroughly trained in the fundamental sciences of physics and mathematics. If it has been accorded to Danish engineers to penetrate to the core of this difficult problem, one of the chief reasons is that our Polytechnic Institute provides such excellent training and inculcates a real understanding of the fundamental and technical sciences. In a small country

like Denmark there is not the rich field for engineering activity and initiative which exists in a country like England with her great natural resources and extensive Colonies. In order to hold our own against world wide competition we must therefore direct our energies towards producing work of the highest standard. I hope that the work which I have described and which has been carried out by Danish engineers will prove to have achieved this high standard.

DISCUSSION.

The Chairman, in opening the discussion, said he thought the audience, after listening to the paper, had something to go home with about which they could think furiously. Dr. Sigurd Smith had probed further into the heart of the mystery than any previous investigator. He had opened all kinds of vistas of thought and investigation and places to be explored, from which results might be expected that would profoundly affect the most important process in the paper making trade. It was a great comfort to him (the Chairman) to think that Dr. Sigurd Smith had written a book to which any one could refer. Without in any way wishing to detract from the paper, it was of a nature which required to be read, pondered upon and digested, and one could do that better with a book than with any paper, however admirably it might have been delivered. The great purpose of the paper had been to awaken interest in the matter, and he thought the author had succeeded in doing that. He desired to compliment Dr. Sigurd Smith not only on his paper, but on his success with the English language. He (the Chairman) had tried to imagine himself addressing a meeting at Copenhagen in Danish, and he was quite certain he should not have succeeded half so well as Dr. Smith had succeeded in addressing the present audience in their own language. He hought that the remarks of the lecturer with reference to Danish engineers and mill managers were really very touching. Dr. Smith was far too modest. Denmark had set an example which English paper makers might very well follow. The author had given in the last part of his address a practical illustration of the sermon which he (the Chairman) was always preaching, namely, that the one hope which the paper making industry in this country had to enable it to meet the competition which came so furiously from abroad was by excelling in technical superiority.

In conclusion, he would like to ask Dr. Sigurd Smith the following questions:—(1) What percentage of the fibres in the fibrage were cut? (2) Could their percentage be increased, and, if so, how? (3) What was the shortest length of fibre which would retain its position on the edge of the bar as part of the fibrage? (4) What should be the best dimensions of the clearance space between the roll and the back fall? (5) Why was there a greater percentage of power used effectively in beating rags as against beating wood pulp? (6) Would there be any advantage in having more than two bed plates? The idea of the duplex beater showed distinctly an advantage with two bed plates. How far was it possible to carry that idea?

Mr. C. F. Cross, F.R.S., said he was able to speak on the matter from a close study of Dr. Sigurd Smith's text book (German translation), which was already recognised by the Research Section of the Paper Makers' Association as a contribution of the first importance and value to the theory of what was, without doubt, the central operation of the paper mill. Dr. Smith now foreshadowed technical progress based on his exhaustive analysis of the complex operation of beating, and gave a general design of a beater constructed to realise, effectively and economically, the potentialities of the factor of beater bar fibrage, for which phenomenon this newly coined word appeared to be an apt description.

Dr. Smith was to be congratulated, first for a splendid piece of work on the best traditions of a scientific-technical investigation, next, for the very clear exposition of the main issue of his investigations, and lastly, for his enterprise in braving North Sea perils, and the worse perils of London in a November epidemic of fog. The Society of Arts was also to be congratulated on giving its *imprimatur* to the work, on its general merit as a contribution to science; in so doing, moreover, it vindicated its own catholic interest in matters technical.

To discuss the matter of the paper would be to presume a specialist interest in the subject, and to anticipate the work of the Paper Makers' Research Section who were about to devote an evening to the full consideration of the subject in all its highly important sectional bearings.

He would limit himself to pointing out: (1) That the special contrivance of bed plate appeared to be an inadequate means of reforming the bar fibrage in the fraction of time involved. (2) That there might be alternative means of securing the intensified fibrage, and, therefore, intensified beating effect, as for instance, in the application of vacuum to the beater roll region, which was a special feature of the Arledter design of beater. (3) The Hydration effects of the beater were essentially chemical effects, if influenced or even determined by the mechanical-physical factors of beating. They were not brought under control by the Duplex beater. He mentioned those points since Dr. Smith's mathematical analytical methods gave the impression of being exhaus-

tively comprehensive. He himself, on the other hand, would have recognised that mathematical method was inadequate to exhaust so complex a field of phenomena. But the work of critical evaluation of the beater of any design, past, present or future, had been greatly facilitated by the lecturer's work, and by the present exposition of the subject. The paper industry was indebted to Dr. Smith, and he was quite sure they were taking steps to express their gratitude in the fullest form and terms.

Mr. William Bacon said that, as the Chairman had pertinently put it, works managers and beater men had produced the goods, but how they had produced them they did not know. For some years works managers had felt the need of some technical and scientific knowledge whereby they could tell how the goods were produced, and the best way of producing them, and the scientific method of arriving at that result. He thought they would receive considerable help from the author's most excellent paper. One of the most interesting points, to his mind, was the question of the stuff travel condition, with that excellent little term, "cell content." As far as he could see, Dr. Sigurd Smith had not given the lineal edge of the fibre. That was rather interesting, because one would think theoretically, apart from any practical considerations, that if the cells could be so increased, and also the number of bars, a beater could thus be obtained which would produce stuff in a quarter of the time in which a beater produced it at the present moment. What he meant was that, supposing Dr. Sigurd Smith had been using a ten millimetre face edge, if that could possibly be reduced to, say, a four millimetre edge, in addition, perhaps, to deepening the lead to the bar between the roll and the face edge, it seemed to him that almost an extraordinary beater would be obtained. Of course, mechanically it would fail, inasmuch as if there were very thin bars it would be more than counteracted by the fact that the bars would so rapidly wear away that the cell content would rapidly drop, and, therefore, its beating capacity would drop. It would be interesting, however, if Dr. Sigurd Smith would give some information about the cell content.

With regard to the frictional losses, as the Chairman had stated, it would be interesting to know the space between the roll and the back fall, because, no doubt, although the loss of power in friction at that stage was important, nevertheless, to his mind, it was far more than compensated for by the fact that when there was a small clearance a better circulation was obtained. It was well known, of course, that where there was a big clearance the beater circulation fell. He would be interested to know if Dr. Sigurd Smith had any information about that point.

The Duplex beater was a most interesting beater. He did not wish to discuss the mechanical side of it, but he could see there were difficulties there, because for a beater to be efficient the two bed plates must be absolutely concentric with the roll, so that when the roll was raised or lowered, both bed plates automatically became at an equal distance from the revolving roll. The interesting thing with regard to the Duplex beater, to his mind, was the formation of the fibrage. Dr. Smith had said that he had found, when the space was allowed to drop—to have quite a good clearance space between the two bars—as a result thereof it caused the fibrage. He would like to ask Dr. Sigurd Smith if he had tried the effect of an air compressor, so that there was a sort of vortex. It seemed to him that in any motion whereby one could get vortexes, one was creating essentials for the formation of that fibrage on the bar. He would like to know if that had been tried.

Mr. R. J. Marx remarked, that if Dr. Sigurd Smith had not stated that the preparation of the report had taken him five years, he would not have believed it possible it could have been done in so short a period. Dr. Sigurd Smith was perfectly correct in saying that work of that description could only be done in the mill. He was certain that every one of the audience felt it a privilege to hear the quintessence of Dr. Sigurd Smith's work in all those years. It seemed to him that the great pity in experimental work of that kind was that there was not a standard beater. Experiments which took such an enormous time could always only be made with a given type of beater, and the consequence was that a number of people who used beaters talked about a beater—each one of them meaning something different from the other. Dr. Sigurd Smith, for instance, had only experimented with stuff consistencies up to a certain low limit. He had generally given his experience that many of the conditions improved as the stuff consistency increased. He had not given his idea of the limits of what the stuff consistency might be. It seemed difficult to reconcile that fibrage idea with some of his own observations, from which it would almost appear that other conditions must be at work additionally. It certainly applied to the ordinary steel or bronze bars of the beater, but what were the conditions when, instead of a steel or bronze bar, one worked, for instance, with a very wide plain stone segment? There one got an enormous amount of hydration. One could only have a very limited fibrage, and yet such stone segments were considered as highly effective. Again, Dr. Sigurd Smith had spoken of the effective power consumption of the roll in the actual beating work. With a certain type of beater he (the speaker) had noticed that the power consumption of the beater when the

roll was down, was scarcely a few per cent. larger than when, in the same beater, the roll was up. It must be remembered that in that beater very high consistencies were used—in some cases up to twenty per cent. He had never seen it lower than eight per cent. But whatever the consistency might be, although there were slight differences in the power consumption of the roll up, and the roll down, the difference was always very small indeed.

He thought on a subject so complex as that of the beater, one could talk for a fortnight at a stretch. Dr. Sigurd Smith had worked on the matter for five years. He himself had given a little time to the subject too, but did not think it would serve any good purpose going into details at that moment, nor was that the place to do so, but he would like to be associated with the other speakers and the Chairman in their thanks to Dr. Sigurd Smith.

Mr. J. Melrose Arnot said he thought every one must concur—whether they agreed with the theory of the formation of the fibrage or not—that Dr. Sigurd Smith had shown them the right way to tackle a subject of that kind. He wished to confirm the fact that if a fresh supply of stuff could be introduced between two bed plates, undoubtedly a bigger beating effect would be obtained. When he had been in charge of the Kösliner works in Germany he had designed a beater which he had called the centrifugal beater, because the bed plates, to use an Irishism, were on the roll, that was to say, the fly bars on the roll were loose. The bed plate was then a continuous plate entirely surrounding the roll; the feed was axially from the end, and the stuff was fed under pressure. The head was about fifteen feet. Sometimes the stuff was obtained too wet, but by altering the consistency of the stuff, just as in an ordinary beater, they were able to alter the beating effect. In one passage through the beater they had attained the result that, on the stuff coming to the machine, after an ordinary hollander had been emptied and worked, the machine man had not realised that the other beater had come to him; that was to say, they had worked that continuous beater right to one chest while the machine was running out of the other chest, and the change over made no difference. There they had had the whole beating effect completed, not in hours, but in minutes. He would never have had the chance of making such an experiment, on account of its expensiveness, but for the readiness of the Germans to adopt any new idea which appeared the least bit feasible. He just wanted to show that, by that means, it was possible to get the feed to each bed plate, and in that way to get a much intensified beating effect.

Mr. J. Huebner said he desired to express his personal indebtedness to Dr. Sigurd Smith for his excellent paper. He had gone a little out of his way to be present, but the paper had much more than repaid whatever trouble he had been put to in that connection. He could only look at the matter from the point of view of the chemist. The mechanical side of the question seemed to have been so thoroughly investigated by Dr. Sigurd Smith, that one could only hope that the chemical question—the so-called hydration in the beater—would be investigated in as thorough a manner. He felt sure that results would be obtained which would be of the utmost value in explaining the beating operation more fully.

Dr. Sigurd Smith, in reply to the Chairman's first question—What percentage of the fibres in the fibrage were cut?—said that his calculations led to the result that one or two per cent. were cut. With regard to the Chairman's second question—Could that percentage be increased and, if so, how?—the roll pressure could be increased, and thereby a larger percentage of cutting could be achieved. The Chairman's third question was—What was the shortest length of fibre which would retain its position on the edge of the bar as part of the fibrage? The answer was that as long as a cutting and abrading action took place between the fly bars and the plate bars, fibres must necessarily form fibrage on the bar edges.

Dr. Smith answered the Chairman's fourth question, namely, What should be the best dimensions of the clearance space between the roll and the backfall by means of a slide representing Plate No. 2? He said that the maximum width, S, of the clearance space at the point A, where the front surface of the back fall became straight could be calculated, assuming that the best width of the clearance space would be that which gave no spitting. It was possible to calculate the speed of stuff, which was necessary in the clearance space at A for the formation of a foundation like that shown in the drawing. Then we had to calculate the width S in such a way that the rate of circulation (*i.e.*, the amount of stuff transported by the roll per second) would pass the clearance space at A with a speed not inferior to that above calculated.

The Chairman had then asked, why was there a greater percentage of power used effectively in beating rags as against beating wood pulp? The reply was that when one was beating rags one was commonly beating with a higher pressure, and, therefore, the beater would naturally consume more power between the roll and bed plates. The percentage of the effective power would, therefore, be larger when beating rags than when beating wood pulp. That was a matter of experience. He had presented the tables No. II. and III., which gave the mean value of numerous tests made by himself, and other investigators. The next question was—Would there be any advantage in having more than two bed plates? Certainly

there would be an advantage. He had never tried three bed plates, but only two, and, therefore, he could not give trial results for such a beater. Where it was possible to put a third bed plate under the roll, he thought it would be an economical improvement.

Mr. Bacon had asked whether it was possible to increase the cell content by making the fly bars thinner and deepening the cells. It would not be of any use in the majority of cases. There was a certain maximum size of fibrage which could not be exceeded. The rod experiments had shown that more than a certain maximum size of fibrage could not be obtained, consequently it would not be of any use increasing the cell content, because beyond a certain limit the larger content would not cause the formation of larger fibrages, and this limit could without difficulty be reached with the ordinary dimensions of the cell simply by ascertaining an appropriate rate of travel. Fig. 2, which he had exhibited, showed the maximum fibrage which could be formed from a certain consistency. The maximum effect was attained when the amount of fibres contained in the cell was about three times the amount of fibres required for forming the fibrage.

Mr. Bacon had also asked how one could ensure that the two bed plates were placed concentric with the roll, and how they remained concentric with it. The first bed plate was put in in the ordinary way, and the roll was let down on this, and the second one could be adjusted by means of wedges on which it rested. The actual beating and the wearing effect on the bars of the bed plate would ensure that the bed plates remained concentric.

Mr. Marx had asked what was the influence of the consistency on the fibrage? He (Dr. Smith) had only had occasion to make beating experiments with consistencies ranging from about 5 to 6 or 7 per cent., so he had really no experience of the high consistencies to which Mr. Marx had referred. The experiments with the steel rod had been carried on up to 8 per cent. consistency, and it had been shown by those experiments that the size of the fibrage increased enormously with the consistency.

In reply to Mr. Marx's question as to how he could reconcile his theory of the fibrage with the action taking place when beating stuff with stone rolls, those stone rolls were made of basalt or lava stones and were really porous. Such a porous stone was in possession of many sharp edges on which the fibrage could be formed.

He thanked the audience very heartily for the attention they had paid to his paper. He was very proud of having been permitted to put his theory before such a distinguished gathering.

On the motion of the Chairman, a hearty vote of thanks was accorded to Dr. Sigurd Smith for his valuable paper, and the meeting terminated.

THE DECLINE OF COTTON-GROWING IN SOVIET RUSSIA.

An article in the *Textile Recorder* gives some interesting particulars relating to cotton growing in Russia.

Cotton in Russia is grown in Turkestan and in the Caucasus. The latter produces just over one-tenth of the total. Cotton-growing in Russia developed very rapidly. For the last five years before the war, the amount of fibre collected rose from 112,000 tons in 1900 to 222,000 tons in 1914, *i.e.*, was almost doubled. The dry deserts of Turkestan were rapidly being converted into cultivated fields which provided a livelihood for the population. The Ministry of Agriculture, under the old regime, expended yearly large sums on the extension of the irrigated area and on experimenting stations. The war gave a new impetus to the cotton industry. The obstacles that have arisen in the way of imports of foreign cotton created favourable conditions for the cotton growers of Turkestan, and in 1915 the harvest of cotton yielded 321,000 tons. In that year, 1,800,000 acres had been sown as against 1,178,900 acres in 1913. The revolution thus found the cotton industry in Turkestan in a flourishing condition.

In the five years of revolution the industry has been well nigh ruined. The organ of the "Soviet for Labour and Defence" (a kind of Bolshevik War Cabinet), the *Ekonomitchskaia Zhisn*, stated, in the issue of July 22nd, 1922, that the sowing area in 1922 will hardly be 189,000 acres. In other words, it will be about ten times smaller than in 1913. The amount of fibre harvested fell still lower, and is not expected to reach the figure of 16,100 tons—5 per cent. of the harvest of 1915. The work of the cotton factories has also been drastically reduced. According to the same paper, the number was 280 before the war, whereas at present only 18 are in working order. The curtailment of the cotton industry does not stop, but continues unabated, and the sowing area is being reduced year after year. According to the above-quoted paper of June 14th, 1921, 216,000 acres were sown—27,000 acres more than this year.

The catastrophic reduction in the cotton industry is due to two main causes. In normal times, bread was imported into Turkestan from Siberia. The yearly average was about 300,000 tons. Owing to the complete chaos now prevailing in that region, and to the absence of means of communication, Siberian bread can no longer be sent to Turkestan, and the cotton-growers, for fear of starvation, have been sowing wheat instead of cotton. Another cause is that fixed prices for cotton have been made compulsory.

There is a cotton monopoly in Soviet Russia. In other words, no one except the Soviet institutions existing for that purpose is allowed

to trade in cotton. The prices fixed by these institutions are considerably lower than the expenses of the cotton-growers. Also payments for cotton are made very irregularly. The population, therefore, has lost all interest in cotton growing, and prefers not to cultivate the fields than to work on a losing concern. In that respect, the attitude of the Turkestan cotton growers does not differ from that of the entire agricultural population of Russia, which prefers to remain half starved rather than surrender the fruits of its labour at a starvation price to the Soviet Government.

The present sowing and harvesting of cotton in Russia are so insignificant that the amount of cotton produced does not suffice for the requirements of the Russian factories that are working at a very low pressure. In 1913, the Russian cotton manufacture absorbed about 500,000 tons of cotton, of which about one-half was of Russian origin. The Bolshevik industry will hardly be able to manufacture more than 55,000 tons, and that is about three times as much as the Russian cotton-growers are likely to harvest. The Soviet Government has already on several occasions purchased cotton from abroad.

There can be no doubt that in their present financial plight the Bolsheviks will be unable to organise the imports of cotton, and the cotton manufactures in Russia may thus be threatened with a shortage of raw material.

GENERAL NOTES.

National Savings Certificates.—The National Savings Committee, of which Lord Islington is Chairman, states that sales of Savings Certificates for the week ended 11th November were 985,133, bringing the total sold to that date up to 601,479,281. The total of six hundred million was reached on 1st November. Dates for the consecutive hundred million totals are as follows :—

100 million Certificates were sold by	30th April, 1917.
200 ,, ,,	28th May, 1918.
300 ,, ,,	26th Feb., 1919.
400 ,, ,,	23rd March, 1920.
500 ,, ,,	26th Jan., 1922.
600 ,, ,,	1st Nov., 1922.

1922 is seen to be the first year in which sales of Certificates have twice passed the additional million mark—a sure proof of the continued attractiveness of this security. One of the reasons for high figures of sales this year is, of course, that the increase of price from 15s. 6d. to 16s. on the 1st April caused a boom in sales before that date. After the boom there was a temporary lull, but sales rapidly recovered, and during the seven weeks preceding the 11th November averaged 1,155,803 certificates a week, which is more than the average for 1921. The 600,000,000 Certificates (combining Certificates at both prices) represent a cash investment of £465,614,148, of which approximately £119,727,000 has been withdrawn, leaving a balance invested of approximately £345,887,148. This means that only about 25% of the whole amount invested has been withdrawn.

Bethnal Green Museum.—Exhibition of Water-Colours by British Artists.—In 1885 Mr. Joshua Dixon, a successful cotton merchant and a judicious collector of pictures, bequeathed to the Bethnal Green Museum the whole of the paintings in his house, Winslade Park, near Exeter, for the benefit of the public of East London, where he was born in 1810. Half of this Bequest consisted of very carefully chosen water-colours by artists of the British School. As a part of the process of re-organisation which the Bethnal Green Museum is at present undergoing, these water-colours have now been re-arranged and are suitably exhibited in the Central Hall, where they are given a prominence they thoroughly deserve. They comprise notable works by some of the most eminent among the founders of the School, including fine examples by John Varley, John Glover, George Barret, Junr., William Hunt, Turner of Oxford, Peter De Wint, David Cox and Copley Fielding. The middle period of the School is represented by such men as Blake's friend Samuel Palmer, F. O. Finch, Louis Haghe, W. L. Leitch and Birket Foster; while the collection is also rich in water colours by artists who were working during the period at which Mr. Dixon was collecting. Among these we can instance the work of George Wolfe, Henry Brittan Willis, Robert Thorne Waite, Alfred Powell and Charles Davidson, who are represented by excellent drawings. The public of East London has never been given a better opportunity of realising what a wealth of beauty has been produced by the water-colour artists of the British School. All who are interested in art should visit the Museum and see these drawings. It is to be noted that inducements to study have been considered in the new arrangements, and seats have been placed conveniently at intervals about the gallery so that the visitor can sit and enjoy the exhibits with the same comfort one expects to have when reading a book. The Museum is open free from 10 a.m. to 5 p.m. on weekdays, and from 2.30 to 6 p.m. on Sundays.

Irish Furniture at the Victoria and Albert Museum.—It appears not to have been generally recognised that, during the 18th century, furniture of a very high standard of execution was produced in Ireland, following the main lines of the English styles of the period but with characteristic differences. A group of examples of this class has now been arranged for exhibition in the Loan Court of the Victoria

and Albert Museum. Those lent by Mrs. Bruce are of inlaid satin-wood, harewood, etc. and consist of a pair of commodes with finely executed decoration in the Adam style, with a pair of tall pedestals and corner-cupboards of similar character. Mrs. Bruce also contributes a pair of small tables and a wine-carrier which correspond more with the style of Sheraton. In addition to these, Captain W. L. Naper has lent a settee and four chairs of walnut, resembling in general design (though differing in detail) English work of the time of Queen Anne.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.*

MONDAY, DECEMBER 11 .. University of London, at the Royal College of Surgeons, Lincoln's Inn Fields, W.C., 4 p.m. Mr. F. W. Twort, "The Nature of Ultra-Microscopic Viruses." (Lecture I.)

Surveyors' Institution, 12, Great George Street, S.W., 8 p.m. Major E. Meacher, "The Agricultural Position and the Possibilities of Stimulating Economic Production in the Future."

Alpine Club, 23, Savile Row, W., 8.30 p.m.

Geographical Society, 135, New Bond Street, W., 8.30 p.m. Prof. J. W. Gregory, "The Alps of Chinese Tibet and their Geographical Relationships."

Brewing, Institute of (London Section), at the Institute of Chemistry, 30, Russell Square, W.C., 8 p.m. Dr. M. H. Van Laer, "New Possibilities of Increasing the Brewer's Extract."

Victoria League, 22, Eccleston Square, S.W., 8 p.m. Prof. F. J. Rousseau, "South Africa: Yesterday and To-day."

TUESDAY, DECEMBER 12 .. Petroleum Technologists, Institution of, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.30 p.m. Mr. T. G. Madgwick, "Some Aspects of the Occurrence of Oil in Russia."

University of London, University College, Gower Street, W.C., 5.15 p.m. Mr. S. Wilberforce, "Customary Law in the Punjab."

At the Royal College of Surgeons, Lincoln's Inn Fields, W.C., 4 p.m. Mr. F. W. Twort, "The Nature of Ultra-Microscopic Viruses." (Lecture II.)

Swiney Lectures, Imperial College of Science, South Kensington, S.W., 5.30 p.m. Prof. T. J. Jehu, "Fossils and What they Teach." (Lecture I.)

Mechanical Engineers, Institution of (S. Wales Branch), 62, Wind Street, Swansea, 6 p.m. Mr. Josiah Butler, "Gas Producers."

Metals, Institute of (N.E. Coast Section), Armstrong College, Newcastle-on-Tyne, 7.30 p.m. Mr. W. Lambert, "Extruded Metals: A Dip into Pandora's Box."

(Scottish Section), 38, Elmbank Crescent, Glasgow, 7.30 p.m. Mr. W. Muirhead, "Nickel: Its Production."

Asiatic Society, 74, Grosvenor Street, W., 4.30 p.m. Mr. C. O. Blagden, "The Malay Peninsula."

Textile Institute, St. Mary's Parsonage, Manchester, 7 p.m. Mr. F. Arrowsmith, "Impressions of the International Cotton Conference at Stockholm (1922)."

Illuminating Engineering Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 8 p.m. Mr. H. T. Harrison, "Recent Developments and Modern Requirements in Street Lighting."

Engineers, Junior Institute of, at the Royal United Service Institution, Whitehall, S.W., 7.30. Address by the President, Captain Riall Sankey.

WEDNESDAY, DECEMBER 13 .. University of London, University College, Gower Street, W.C., 6.15 p.m. Mr. A. W. Flux, "Foreign Exchanges." (Lecture VI.)

Mechanical Engineers, Institution of (Midland Branch), at the University, Edmund Street, Birmingham, 7.30 p.m. Dr. T. E. Stanton, "Some Recent Researches on Lubrication."

Literature, Royal Society of, 2, Bloomsbury Square, W.C., 5.15 p.m. Prof. E. Gosse, "The Centenary of Matthew Arnold."

Industrial League and Council, Caxton Hall, Westminster, S.W., 7.30 p.m. Mr. J. Lort-Williams, "The Only Remedy for Unrest."

Public Health, Royal Institute of, 37, Russell Square, W.C., 4 p.m. Dr. C. W. Saleeby, "Sunlight and Childhood."

THURSDAY, DECEMBER 14 .. African Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5 p.m. Rev. J. Roscoe, "Uganda and Some of its Problems."

Metals, Institute of (London Section), at the Institute of Marine Engineers, 85, The Minories, Tower Hill, E., 8 p.m. Dr. P. Longmuir, "Brass Foundry Practice." Joint Meeting with British Foundrymen.

Linnean Society, Burlington House, Piccadilly, W., 5 p.m.

Chemical Society, at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W., 8 p.m. Dr. C. H. Desch, "The Metallurgical Applications of Physical Chemistry."

Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C., 6 p.m. Mr. J. Caldwell, "Electric Arc Welding Apparatus and Equipment."

Swiney Lectures, at the Imperial College of Science, South Kensington, S.W., 5.30 p.m. Prof. T. J. Jehu, "Fossils and What they Teach." (Lecture II.)

Structural Engineers, Institution of, 296, Vauxhall Bridge Road, S.W., 7.30 p.m. Mr. Ingerslev "The Strength of Rectangular Slabs."

Historical Society, 22, Russell Square, W.C., 5 p.m. Miss Irene Wright, "The Capture of Jamaica in 1655."

British Decorators, Institute of, Painter's Hall, Little Trinity Lane, E.C., 7.30 p.m. Mr. M. Drake, "The Making of a Stained Glass Window."

Optical Society, Imperial College of Science, South Kensington, S.W., 7.30 p.m. Mr. T. Smith. (a) "A Large Aperture Lens not corrected for colour." (b) "The Optical Cosine Law."

Chadwick Public Lecture, at the Royal Society of Medicine, 1, Wimpole Street, W., 5.15 p.m. Sir Arthur Newsholme, "Relative Values in Public Health." (Lecture II.)

Camera Club, 17, John Street, Adelphi, W.C., 8.15 p.m. Mr. W. Sanderson, "Florence and Some Cities of the Etruscan League."

Central Asian Society, at the Royal United Service Institution, Whitehall, S.W., 5 p.m. Colonel S. F. Muspratt, "Afghanistan."

Society for Constructive Birth Control, Essex Hall, Strand, 8 p.m. Dr. Jane Hawthorne, "Birth Control as it affects the working Mother."

FRIDAY, DECEMBER 15 .. University of London, at the Royal College of Surgeons, Lincolns Inn Fields, W.C., 4 p.m. Mr. F. W. Twort, "The Nature of Ultra-Microscopic Viruses." (Lecture III.)

Swiney Lectures, at the Imperial College of Science, South Kensington, S.W., 5.30 p.m. Prof. T. J. Jehu, "Fossils and What they Teach." (Lecture III.)

Mechanical Engineers, Institution of, Storey's Gate, S.W., 6 p.m. Mr. G. Lumley, "Reclamation Plant and its Operation."

(Midland Branch), at the University, Edmund Street, Birmingham, 7.30 p.m. Annual Lecture to Graduates.

Announcements intended for insertion in this list must be received at the SOCIETY'S Office not later than the Monday of the week preceding the Meeting.

*For Meetings of the ROYAL SOCIETY OF ARTS, see page 37.

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

NOTICES.

FIFTH ORDINARY MEETING.

WEDNESDAY, DECEMBER 6th, 1922; MR. LAURENCE CURRIE in the Chair.

The following candidate was proposed for election as a Fellow of the Society:—

Toplis, Henry, A.M.I.Mech.E., Burnage, near Manchester.

The following candidates were duly elected Fellows of the Society:—

Burns, Robert, Houghton, Co. Durham.
Horton, George Craigen, Liverpool.
Jana, Dr. Ashutosh, M.Sc., LL.B., Bengal, India.
McNish, Colonel George, C.B.E., Glasgow.
Maxwell, Marshall Andrews, B.Sc., Huntingdon, West Virginia, U.S.A.
Puech, Lieut-Colonel A. G., O.B.E., V.D., Delhi, India.
Traphagen, Frank W., Ph.D., Los Angeles, California, U.S.A.
Trollope, Clifford Cecil, London.

A paper on "Recent Developments in the Manufacture of Safes and Strong Rooms" was read by MR. H. EMORY CHUBB.

The paper and discussion will be published in a subsequent number of the *Journal*.

CANTOR LECTURE.

On Monday evening, December 11th, PROFESSOR W. A. BONE, F.R.S., delivered the third and final lecture of his course on "Brown Coals and Lignites."

On the motion of the Chairman, PROFESSOR HENRY E. ARMSTRONG, F.R.S., a vote of thanks was accorded to PROFESSOR BONE for his interesting course.

The lectures will be published in a subsequent number of the *Journal*.

LIST OF FELLOWS.

The new edition of the List of Fellows of the Society is now ready, and copies can be obtained on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.

INDIAN SECTION.

FRIDAY, NOVEMBER 17TH, 1922.

SIR THOMAS H. HOLLAND, K.C.S.I., K.C.I.E., LL.D., D.Sc., F.R.S., F.G.S., Rector of the Imperial College of Science and Technology, in the chair.

The paper read was:—

THE DEVELOPMENT OF WATER POWER IN INDIA.

BY J. W. MEARES, C.I.E., F.R.A.S., M.INST.C.E., M.I.E.E., M.I.E. (Ind.)

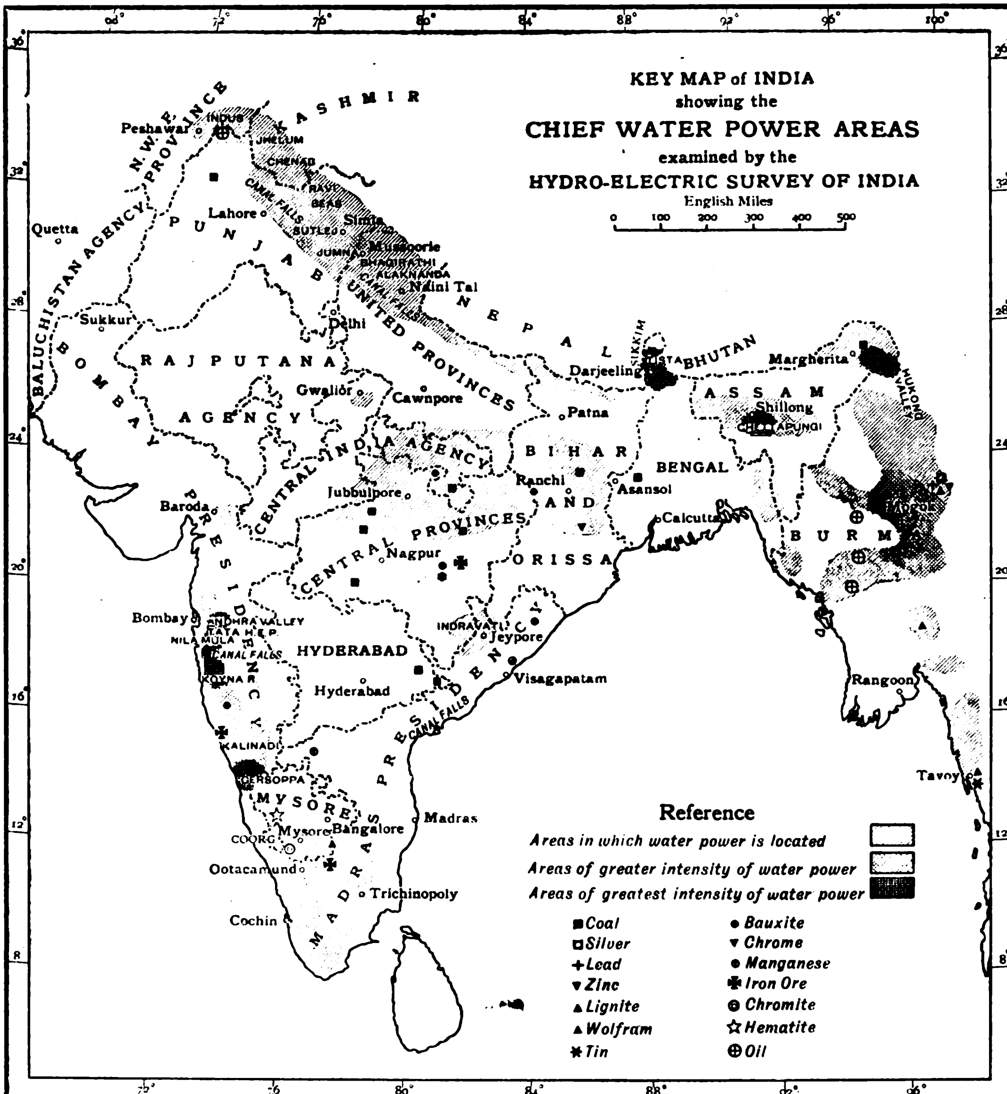
In responding to the invitation given to me to address the Indian Section of the Royal Society of Arts on the subject of the water power of India, I am practically in the position of delivering a funeral oration. For the Hydro-Electric Survey of India is moribund and I cannot see any likelihood of its resurrection. Nevertheless it has left some useful material behind it, and we must look rather to the development of the power already located than to further search for new sites.

During the past year, two papers have been read in London, dealing with certain aspects of the problem, so that I must endeavour to avoid overlapping. It was unfortunate that Mr. Arnall's lecture,* delivered before the East India Association, was printed before my third report reached him. I shall have occasion to refer to some points raised by him. Before dealing with recent results I think a little early history may with advantage be mentioned.

FIRST BEGINNINGS: DARJEELING; CAUVERY RIVER.

The first water-power developed in India was for use on certain tea gardens in the Darjeeling district, the turbines driving the factory machines either directly, or through

* "Hydro-Electric Power in India," a lecture delivered before the East India Association on February 20th, 1922, by Arthur T. Arnall, B.Sc., etc., with discussion.



Emery Walker Ltd. sc.

wire rope transmission, and in one case electrically. At the last named the problem of firing or drying tea electrically was the subject of experiment about 1897, but nothing came of it owing to the fact that the amount of power required was greatly underestimated. I shall have a word to say on the subject presently.

In 1896 I was sent out to India by Messrs. Crompton and Co., with whom I had served my pupilage, to erect the first public hydro-electric scheme in India, for the Darjeeling Municipality. A contract for this work had been entered into by Messrs. Kilburn and Co., of Calcutta, who afterwards started the Calcutta Electric Supply Corporation on its triumphant progress.

The Darjeeling single-phase installation was a very small affair, but it marked a beginning. The following year the Burma Ruby Mines put up a two-phase water-power installation at Mogok. Both these old plants are still at work, as also are old installations at two cotton mills, worked from canal power.

In 1898 I was appointed Electrical Engineer to the Bengal Government, and during my tenure of that post there were no further developments in British India, though the Cauvery plant in Mysore was started early in the 20th century to meet the demands of the Kolar Gold Fields.

THE FIRST ELECTRICITY ACT.

While I held this post the question of electrical legislation came up and it fell to my lot to draft the Indian Electricity Act of 1903.* *Inter alia* this Act provided a simple method by which transmission of power lines could be laid across country in a land of small holdings. The powers as to wayleaves which the Telegraph Department possesses can be given to the promoter, and in the case of water-power this is almost always essential. This question of way-leaves has always been a great stumbling-block in England. I have re-examined the section of the Act referred to, in its present form,† and the notifications issued under it, and I do not think that it requires amendment as has been urged by other writers.

Two years later I became Electrical Adviser to the Government of India.

In the first decade of this century various hydro-electric schemes took their rise. Among these was the hill-station of Mussoorie, and here my Darjeeling experiences were of service. I had occasion to visit these works during construction, to report on the exercise of the special powers of the Electricity Act with regard to the short transmission line. But I went beyond my mandate and reported that the pipe line was unsafe where it crossed a stream. I remarked :—"It may be this year or ten years hence, but sooner or later there will certainly be an abnormal rainfall and the pipe will then be washed away." The Government of the United Provinces were very annoyed and asked the Government of India what right I had to butt in in matters of civil engineering that in no way concerned their Electrical Adviser. Within a few weeks of the receipt of a mild reprimand my prophecy came true in every respect, and I was telegraphed for in great haste by the very people whose toes I had trodden on.

FLOODS.

I have mentioned this because the whole of India is liable to unforeseen floods of the same sort, far more than countries which do not have a monsoon. I will give two other instances.

* Repealed by the Indian Electricity Act, 1910, which in turn has been amended by the Indian Electricity (Amendment) Act, 1922, and by the Devolution Act, 1920. *The Law relating to Electrical Energy in India*, second edition, Thacker, Spink & Co., Calcutta.

† *The Law relating to Electrical Energy in India*, 2nd edition page 244, *et seq.*

While looking into the possible electrification of the Nilgiri Railway, Mr. C. F. Sykes and I examined records of rainfall for 30 years and were prepared to fix our probable flood level at the power station site on these records. Then an old tea planter in the club told us that he had been there for 45 years and remembered a far greater flood than any we had heard of, when he first came out. This, he said, rose well over the Coonoor Bridge and about six feet higher than the highest we anticipated. His friends jeered at him, but this flood was repeated about a year later, and confirmed his memory exactly.

Finally, the late Mr. Barlow and I were examining falls in the Narbada and looked up the flood records at Mandleswar. The highest rise shown was some 40 feet, recorded on the steps of the ghat as having occurred 50 years before. I think this was in 1864, when 10½ inches of rain fell in the Narbada Valley in 18 hours.* But here again the oldest inhabitant came along and told us that there was a flood-mark much higher up. After a lot of search we found it, at 53 feet, the date being over 90 years ago. Thirty years, the usually accepted period, is, therefore, too short in India.

THE TATA HYDRO-ELECTRIC POWER SUPPLY CO.

A great landmark in the history of water-power in India was reached when Messrs. Tata started work on the first of their great projects in the Western Ghats, near Bombay. These undertakings were the first, I believe, to depend entirely on the storage of a three-month monsoon behind large dams; but so much has been said and written on the subject that I need not refer to it further except to say that the third of their schemes, the Nila-Mula project, has been held up for years by the Gandhi movement and the defects of the Land Acquisition Act.

MORE LAW.

In 1910 the present Indian Electricity Act became law, and in various respects eased the position as regards water-power and the attendant transmission lines. In particular it amended the existing law with regard to Land Acquisition, but that law requires a great deal more amendment before it will really serve the purposes of

*Blandford, quoted by Buckley.

the industrialist. In 1920 and 1922 the Electricity Act itself was further amended.* and it is generally conceded to be an up-to-date enabling Act, with not too much red tape about it. Mr. Arnall, however, has pointed out a defect, in that it is not clear whether a hydro-electric generating station includes all the hydraulic works connected with it, in the purchase sections.† I think the term would certainly be held to include these, but it is a pity that the matter was not referred to me, as I could have put it into the Amendment Act of 1922 without any difficulty. The Amending Bill was before the country for two or three years and very few useful suggestions came from the industry.

FIRST ATTEMPT AT A SURVEY.

To come to the Hydro-Electric Survey, it is to Sir Thomas Holland's foresight that we owe what little has been done. So long ago as 1905, when Director of the Geological Survey, he recommended the Government of India to ask Local Governments for information as to the water-power resources of their provinces in connexion with the great bauxite deposits. The enquiry, however, came to nothing. A circular was issued to Local Governments, vaguely enquiring what water-power the province contained. No explanation was vouchsafed as to what was meant by water-power, nor how it was to be assessed. The result was what anyone could have foreseen. There was a large and rapidly flowing river here—perhaps with a fall of six inches to the mile—and a reservoir site at *the foot* of a hill there; and a waterfall was believed to exist in yet another place, on a river which is, perhaps, stone dry for five months in every year. All this was duly printed up, but the powers-that-be decided that it should not be published, possibly because they realised how futile it was.

Thus was a great opportunity lost at a time when money and men were easy to obtain. There was not even a request to start the systematic gaugings of rivers and streams; and in post-war days very little has been possible in this respect. It has been said that a great deal of information on these subjects had already been recorded by various agencies and that "in a few years all essential information for the development of India's water-power resources should be available in a concise form for general use." All I can say is, we have been unable to find this information, except as regards irrigation rivers; and so far as I know practically nothing is being done in the matter now.

During the period from 1905 to the outbreak of the war a few additional installations were put up, but no steps whatever were taken to ascertain the water-power resources of India. Meantime her mineral resources were being thoroughly investigated and there was desultory talk of electrifying suburban railways and so forth.

THE OUTBREAK OF THE WAR: CORDITE; NITRATES.

Then India took her place in the Great War, and began to take stock of her position. I happened to go down to the Government Cordite Factory near Wellington soon after the outbreak to look into some small question of establishment. I found that the storage reservoir on which the hydro-electric plant depended during the dry weather was so silted up that a partial failure of the next N.E. monsoon would almost certainly shut the works up. Once again I butted in with an opinion not asked for, seeing that I knew that the anti-air-craft cordite was all being made there. This time I simply stated the position, and the remedy—viz., a further upstream reservoir—in an interview at Army Headquarters, and I believe that the speed with which action was taken beat all previous records.

It soon became evident that the war would not be over quickly, and that nitrates were likely to be an important factor. Enquiries were then sent flying round as to whether any sites existed where from 25,000 horse-power upwards could at once be developed for munition industries. With the exception of the Koyna River site, there was practically no information beyond the replies to the Government's famous circular letter. The Koyna Valley, with its 650,000 horse-power, is in pickle for the next war.

THE INDIAN INDUSTRIAL COMMISSION.

Next followed Sir Thomas Holland's Indian Industrial Commission. In my evidence, I put forward a written statement urging the importance of a reconnaissance survey of water-power resources,

* By the Devolution Act, 1920, and by the Indian Electricity Amendment) Act, 1922.

† Sections 3 (2) (d) (ii) (ii), 5 and 7.

and in their report the Industrial Commission urged the Government of India to undertake the work. The paragraph embodying the recommendation pointed out that only Government could deal with the displacement of agriculturists by reservoir schemes and the consequent acquisition of land; with the long period gaugings necessary, and with questions of concessions, often overlapping State boundaries and involving both power and irrigation.

With a touching faith in the omniscience of the Public Works Department, the Commission recommended that a Chief Engineer of that Department should take the survey in hand, and with astonishingly little delay the Government of India took action. Their first impulse was, of course, to appoint another peripatetic Commission or Committee. It was, however, speedily seen that progress did not lie in that direction. Before the end of 1918 they appointed the late Mr. G. T. Barlow, C.I.E., as Chief Engineer, and associated me with him for the electrical side of the work. No better choice could have been made than Mr. Barlow, and his untimely death was a great loss to me personally, and to the work in hand. Mr. Barlow had immense experience in irrigation, and particularly reservoirs, and believed that practically all projects would turn out to involve large scale storage of water. He was somewhat amused when I told him that it would be years before actual problems of reservoir construction would come up, and that we were never likely to reach the electrical stage at all. That, however, has proved largely true.

INITIAL STEPS.

During the course of our first and last tour together, we found that between us we could carry out our task. Our first object was to educate the persons who would be likely to help, and to this end we printed several pamphlets setting forth in the most elementary fashion the principles on which water-power is based, the places in which to look for it, and the methods to be employed in collecting data. We interviewed the Secretariats, local civilian administrators, engineers, forest officers, missionaries and oldest inhabitants. During this tour we enlisted the sympathy of the Local Governments—not a difficult task when they have not to find the money—and arranged for engineers to superintend the work in the Provinces under our technical direction.

The information we collected was published in a Preliminary Report*, a few months after Mr. Barlow's death, and demonstrated for the first time the magnitude of the work. A good many Local Governments appointed irrigation engineers to take charge of the local work, for which the funds and supervision were supplied by the Government of India.

I have always had what is known as a "bad Press." The daily papers which count generally take no interest whatever in technical subjects, though they will sometimes print your own articles as a favour. Technical papers do not reach the people who influence matters, and infinitely more interest was taken in this report in America (where the plant comes from) than in India.

In due course, the Government of India appointed Mr. F. E. Bull to succeed Mr. Barlow, and a second or interim report† was issued by us on the season's work of 1919-20. Then the reforms came into active being, and Mr. Bull retired, leaving me to carry on under the new conditions.

THE REFORMS AND THEIR EFFECT.

Now, as every one knows, the Reform Scheme divides all subjects up primarily into "Central" or Imperial and "Provincial," and secondarily into "Reserved" and "Transferred" subjects. I am not at present concerned with politics, but I should like to say this. The Government of India undertook the Hydro-electric Survey and promised to find funds for it; it was estimated to take only about five years, of which two had elapsed in spadework. Surely it must have been evident that if they then divested themselves of all financial responsibility the Survey would be starved. That is exactly what happened in most provinces. The new Councils saw certain sums appropriated to the Survey and pounced upon them, with the result that a good deal of the work was curtailed or stopped. Could not this temporary work of the most vital importance have been allowed to remain Imperial for three more years?

THE TRIENNIAL REPORT.

What has been achieved? Considering that the task has been one of Pharaoh's

* Preliminary Report on the Water Power Resources of India, 1919.

† Second Report on the Water Power Resources of India, 1920.

setting I think the tale of bricks is satisfactory. I brought all the information together in a Triennial Report* issued in 1921, and obtainable through any of the agents for the sale of Government publications.

The first part of that report is an illustrated text-book on water-power, which may be commended to the writers of volumes on the subject, who for the most part never go beyond the lifting dam type of development, as though that were the only one.

The second part summarises our knowledge of the resources of India up-to-date. The figures in the report are all given in kilowatts, but I will speak here in horsepower. With such sketchy data as are available there has been no need to go into decimals.

Until quite recently the water powers of Great Britain have been tacitly ignored, as the country prefers to live on its capital in the form of coal. The fact is well illustrated by reference to most British catalogues of turbines, in which the flow of water is given in gallons per minute! If one is dealing with a 10,000 h.p. turbine under a low head of say 10 feet the water required would amount to about 11,000 cubic feet a second, which is unwieldy enough; but expressed in gallons per minute it is a matter of 4 millions! Our reports have throughout estimated the flow of water in cubic feet per second or "cusecs," which is a more expressive term than the American "seconds-feet." I particularly like the unit and the term because it is an exact hydraulic equivalent of the ampere in electrical terminology.*

All through the report I have taken one-fifteenth part of the product of the minimum flow of water, multiplied by the available head in feet, to represent a kilowatt or $\frac{3}{4}$ of an electrical horse-power (e.h.p.) in the output of a developed site. In the case of storage projects, or combined flow and storage, the minimum flow is that which we think can be continuously depended on even in a series of dry years.

THE POWER IN ESSE AND IN POSSE.

Some 350,000 e.h.p. have been developed or were under construction in 1921.

The Survey had definitely examined sites capable of giving a further $1\frac{1}{2}$ million e.h.p. continuously throughout the year.

There are known sites, not fully examined, capable of giving more than a further $1\frac{1}{2}$ million e.h.p. continuously.

Then there are more speculative sites, of which little is known except that both the water and the distributed falls exist, which I put down in the report as probably good for a further 4 million e.h.p. In making this last guess each river or site is mentioned and assessed, and quite as many will have been under as over-estimated. Yet there are hundreds of other cases where I was unable even to hazard a guess.

POWER ON ORDINARY MINIMUM FLOW AND FOR MAXIMUM DEVELOPMENT.

It is perfectly safe to say that at least 7 million e.h.p. is in sight on the most conservative estimate and on the basis of *absolute* minimum continuous power. This, however, is a basis seldom used in other countries. The Dominions Water-Power Branch of Canada* defines "*ordinary* minimum flow" as "based on the averages of the minimum flow for the two lowest consecutive seven-day periods in each year, over the period for which records are available." The same body defines the "estimated flow for maximum development" as "the continuous power indicated by the flow of the stream for six months in the year. The months are arranged according to the day of lowest flow in each; then the lowest of the six high months is taken as the basic month; and the average flow of the lowest seven consecutive days in this month determines the maximum *for that year.* The average of such maxima for all the years used is taken as the estimated maximum used in the calculation."

I have given the probable "ordinary minimum power," which it will be seen ignores occasional short-lived droughts, as ten million e.h.p.; and the probable power for "maximum development" as about 17 million e.h.p. These are large figures, and will provide for industrial needs for a considerable time.

At present very little information has been collected as to the probable cost of development. Hitherto reconnaissance has been the order of the day, and survey is necessary before capital costs can be estimated. It is, however, often possible

* Hydro-Electric Survey of India; Triennial Report, with a preliminary forecast of the Water-Power Resources of India. 1922.

* Vide Preface to *Electrical Engineering Practice* by the present writer.

* Leaflet No. 536, dated Ottawa, the 30th, May 1921.

after examination to say whether a project will be cheap, average or expensive; and in many cases my report gives this information.

I need hardly say that costs have gone up enormously in the last ten years, although they are slowly dropping again. But the cost of fuel is going up also, and upon that depends the practicability or otherwise of a hydro-electric project with its long transmission. The old notion that "water-power costs nothing" has long since been exploded, except in the popular mind.

INDIA AND INDUSTRIES.

I turn aside for a moment to the attitude of India towards industrial development. At the present moment, except for cotton and a few other things, the industrial development of India has been carried out by British capital and enterprise. Clearly these will not, as matters now stand, expand to an extent requiring more than a small fraction of all this power that is running to waste. But hitherto the Indian, although an extensive shareholder in British companies, has not been conspicuously successful as a pioneer. In one province I discussed the matter with some candid politicians. Their attitude was this:

"We are quite content in our present backward state. Our people can now do as much or as little work as they like without danger of starvation. If you bring your power and your industries here, prices will go up and we shall all have to work in order to live. We dislike your industries; we do not want your capital or your engineers; we simply wish to be left alone in our 'pathetic contentment,' except as regards political power."

Nevertheless, the cry for technical education is unceasing. What these technically educated men are going to do, if there are no industries, is hard to envisage; and without cheap power and (as Sir Thomas Holland has pointed out) cheap sulphuric acid there will be few industries.

That, I believe, is the real attitude over the greater part of India. That is why local Councils will not vote funds for the continuance of a survey which threatens to assist the industries foreshadowed by the Indian Industrial Commission.

I have already pointed out that our investigation was considered to be almost part and parcel of the irrigation work of Government. It is so in this sense; that if the development of water-power is likely to interfere with an irrigation scheme the power would have to go. Irrigation is certainly the more vital of the two. There is, however, this difference, that the water used for power comes back undiminished and unaffected at the tail race, whereas an irrigation canal finally tails off to nothing after all its water has gone on the land. High-level irrigation by electrical pumping certainly has a future before it, so has subsoil pumping.

A famous Viceroy, visiting the Sirhind Canal, is reputed to have enquired into what river it finally discharged; but until the Triple Canal Project did actually transfer water from river to river, across the Punjab, there was but little water over at the far end of any canal. Consequently, during the dry season, the power of the great irrigation rivers is confined to the falls in their canals or to the reaches above the head works, in the hills behind.

On the other hand, I have often been asked what percentage of the water is used up in the generation of power, as though it were evaporated in a boiler and discharged into the air in some fashion.

It is very hard to kill the notion that rivers like the Ganges in the plains, or the Hooghly above Calcutta, can be commercially harnessed by placing undershot water-wheels across the whole bed. Many responsible business men have put this matter to me and have evidently not quite accepted my verdict that the game would not be worth the candle, apart from the floods that would result upstream and the frequent disappearance of the few inches of head so obtained. The rapid current has an irresistible attraction; but what we must have is a definite fall.*

Echoes have reached us of a proposal to spend 30 million pounds on a tidal power,† which is hopefully expected to supply electricity at a half-penny per unit. Such a price would, of course, be prohibitive for electro-chemical work, but it would be positively cheap compared with the power obtained from a river with a bed slope of a few inches to the mile. I may mention that, for electro-chemical work, it is generally reckoned that power must be delivered at a cost of from one-tenth to one-fifth of a penny per unit. Such prices

* See also the Final Report of the Water Resources Committee of the Board of Trade, para. 135.

† Third Interim Report of the same Committee.

are never likely to be obtained from tidal power or any but ideal river or storage schemes.

TRANSMISSION OF POWER AND OF MATERIAL.

It generally happens that really cheap sources of water-power are at a great distance from any industrial centre. If fuel is very expensive long transmission lines may be justified and necessary, but the capital cost of the transmission line, its maintenance charges, the power lost in transmission and the capital cost of the useless plant supplying those losses, all combine to increase the final cost of the power delivered.

The alternative, often adopted, is to bring the industries to the power; but this, again may necessitate constructing railways and incurring the cost of freight both on the raw material forward and on the finished product backwards. I heartily agree with Mr. Arnall that one of the best forms of Government assistance will be in the matter of roads and railways to sites under development; but in these days I doubt if money will ever be voted for such an object.

FULL AND PARTIAL DEVELOPMENT.

A difficulty almost always encountered is that a hydraulic development *must* be designed, and for the most part constructed, for the full ultimate capacity of a site, although it may be many years before all the power is required. Plant and pipe lines can be laid down as required, but headworks, dams and channels can seldom be laid down piecemeal. It is true that a dam can be raised, if so designed, or shutters can be added to it; but the cost is nearly all at the bottom.

Occasionally it happens that nature arranges matters so that gradual development is possible, but I have met with very few cases of the sort. I recently examined one such in Ceylon, which I believe is now being developed in its first stage. This Laxapana-Aberdeen scheme merits a few remarks. It is a quadruple one. There are two streams with a large perennial discharge, in the hill area, meeting at a point near which the power station will be built. Above that point there is a steep hillside, admirable for a pipe line, leading up to a point 2,000 feet higher up where the forebay would be placed. From each stream an open channel of a few miles in length will bring the water up to this forebay, only a short stretch being common to both. One stream is to be developed first; the other can be led in when required. When these have both been utilised and developed, there are reservoir sites higher up in both streams, where considerable volumes of flood water can be stored to supplement the minimum discharge. About 100,000 h.p. can be obtained continuously.

There are large demands for power in Colombo, but the site is right in the middle of the tea growing area. In the Triennial Report, I have given some extracts from my Ceylon report on the subject of tea-drying electrically. The problem is a perfectly simple one, capable of fairly exact calculation, and there is not the slightest doubt that there is money in it when tea companies awake to the fact. I have dealt with it fully in my Reports.

I mention this, because in north-eastern India, where the chief tea growing districts are situated, there is also plenty of water power available; but the late slump in tea, combined with the high price of machinery and labour difficulties (ultimately traceable to non-co-operation) have so far combined to prevent the realisation of a project actually drawn up for the Duars district, on the Jaldaka River, and the prospects are not very bright.

CONCESSIONS; INTEREST DURING CONSTRUCTION; ROYALTIES.

Before giving a short summary of our principal results, I must say a word on concessions. During the discussion on Mr. Arnall's paper this matter came up, but the speakers had not then received my report. They urged the necessity of clear orders on the subject of granting water power rights. I had, in fact, drafted a form of concession a year earlier, and it was in the Secretariat for a very long time. Finally, Government decided not to issue any "Model Form," but to leave me to do this. The form as it left Government, is printed at the end of the Triennial Report, and the question of legislation was under consideration when I left India.

An important point raised by Mr. Arnall is that of paying interest out of capital during construction. For years to come, at any rate, the present rate of 4 per cent. is clearly inadequate. One would have expected the Department of Industries to have initiated legislation to amend the

Indian Companies Act on this point long ago. It is a very important one.

A point on which I have never been able to see eye to eye with Government is that of royalties on water-power in India, though, of course, I have accepted their views as voiced by Sir Thomas Holland. Talk as we will, there are no great signs of the industrial era coming in. The one thing that may help it along is really cheap power. I see little prospect of Government constructing works and supplying that power, except for a specific purpose, so it must be done by business people—and it will, in my opinion, be done far better that way. But any tax on power is passed on directly to the consumer, as in every parallel case. I will allow that a royalty of five or possibly even ten, rupees per horse-power year may bring in a good revenue, to pay for further survey, and as a political point that is good. There are cases now where ridiculous royalties are being paid, and I had to deal with one proposal to impose a tax greater than the total cost of the fuel which the water-power was to save. I would prefer, therefore, to see business men taking up schemes and paying good dividends on them, unhampered by taxation.

THE WATER POWER RESOURCES OF INDIA.

The map accompanying this paper shows the chief areas in which water-power has been located, according to the intensity of the shading. The map is reprinted from the Triennial Report already referred to, as are also the following tables :—

TABLE I.—SUMMARY OF PROBABLE MINIMUM CONTINUOUS WATER-POWER IN INDIA.

Province or State.	Water Power now developed (site capacity) K.W. continuous.	Plants under construction. K.W. continuous.	Areas investigated but not developed. K.W. continuous.	Known sites of which detailed examination is desirable. Probable K.W.	Areas and sites not investigated. Probable K.W.	Probable total. K.Ws.
1	2	3	4	5	6	7
Assam	...	...	109,000	5,000	300,000	414,000
Baroda	...	...	4,000	...	...	4,000
Bengal (1)	600	...	14,250	5,000	650,000	669,850
Bihar and Orissa	...	...	12,550	20,000	30,000	62,550
Bombay	71,400	50,000	272,560	230,350	20,000	644,310
Burma	3,370	...	155,800	492,400	300,000	951,570
Central India	...	...	280	400	...	680
Central Provinces and Berar	...	...	13,700	113,860	10,000	137,560
Cochin...	...	...	4,000	...	...	4,000
Coorg	...	...	...	1,500	...	1,500
Gwalior	...	1,000	42,300	...	...	43,300
Jammu and Kashmir ...	105,830	...	...	179,500	20,000	305,330
Madras	740	...	32,670	53,900	5,000 × x	92,310
Mysore	24,000	4,500	20,000	...	...	48,500
North-West Frontier ...	[250]	...	...	...	[1,000,000]	[1,000,000]
Patiala	290	...	...	...	...	290
Punjab and canals (2) ...	1,880	...	129,270	See cols. 4 & 6	662,000	793,150
Rajputana	...	...	...	160	...	160
Sikkim	...	...	5,000	...	...	5,000
Travancore	450	...	...	...	...	450
United Provinces and canals	4,330	140	378,900	See cols. 4 & 6	20,000	403,370
TOTALS ...	213,140	55,640	1,194,280	1,102,070	3,017,000	5,582,000

(1) Survey just beginning.
(2) Ditto. Probably greatly under-estimated.

Of the projects or sites included in the above summary, the following list shows the order of magnitude of the projects suggested or known; but as regards the first entry, only 4,000 k.w.'s can be developed on the present layout of open channel :—

TABLE 2.—ORDER OF MAGNITUDE.

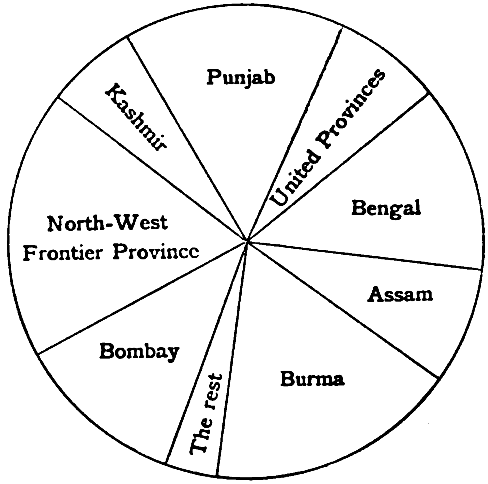
Minimum power available, K.W.	Developed.	Under construction.	Investigated.	Known, but not fully examined.	Probable.	Possible.	Total.
Over 100,000	1*	...	1	3	No indication is possible.	No indication is possible.	5
50—100,000	...	1	1	2			4
20— 50,000	3	...	6	5			14
10— 20,000	...	...	6	14			20
5— 10,000	...	...	9	10			19
1,000—5,000	3	2	29	29			63
Total ...	7	3	52	63	...	...	125

Using certain factors given in the report, Table 3 shows the probable "ordinary minimum power," and the probable "power for maximum development" on the Canadian basis; but many large rivers are left out of account for lack of information.

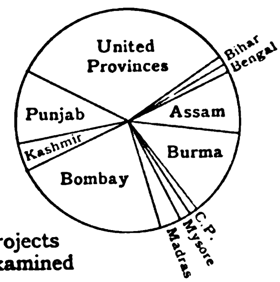
TABLE 3.—SUMMARY OF ORDINARY AND MAXIMUM POWER.

Province or State.	Probable ordinary minimum power:	Probable power for maximum development:
	K.W.	K.W.
Assam	621,000	1,200,000
Bengal	1,000,000	1,500,000
Bihar and Orissa ...	95,000	150,000
Bombay	773,000	1,000,000
Burma	1,327,000	3,000,000
Central Provinces	165,000	180,000
Jammu & Kashmir	458,000	650,000
Madras	138,000	300,000
N.W.F. Province ...	[1,000,000]	[1,000,000]
Punjab	1,190,000	2,400,000
United Provinces ...	605,000	1,000,000
Other areas entered in preceding table	160,000	300,000
Total ...	7,532,000	12,680,000

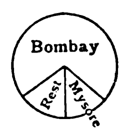
The three diagrams following (also culled from the Triennial Report) give some general idea of the distribution of the known power, the investigated power and the developed power.



(i). Probable minimum power



(ii). Projects examined



(iii). Plant installed

THE PROVINCES: ASSAM.

After Mr. Arnall's Koyna Valley scheme in Bombay Presidency, I think the next best project is probably a storage one in the Hukong Valley, in the far north of Assam. Here a fall of 2,000 feet can be obtained by means of a short watershed tunnel through the Patkai Hills, and some 90,000 e.h.p. can be obtained continuously with what is likely to prove a cheap hydraulic development. Unfortunately, the place is very remote from civilisation, and its nearest neighbours are coal and oil fields. At present an armed guard is necessary to anyone going there. The site, however, is on the route of the surveyed railway link between Assam and Burma. A few years ago the *Times* was telling people that it was a scandal that there was no such

connection. That was when the Emden was in the Bay. Now the Emden has gone, and we can go to sleep comfortably again.

Assam generally has a large amount of potential power; far more than is needed to make the whole of the tea which supports the province. It also has the purest limestone in India, in the Cherrapunji area, and the development of a nitrate industry has consequently always been kept in mind. The Cherra plateau drops about 4,000 feet sheer into Sylhet, and has a mean annual rainfall of over 400 inches, but it has, nevertheless, proved disappointing. There is only one passable reservoir site in it, and that will not contain a fraction of the enormous rainfall—even if the limestone proves suitable for a reservoir at all. It may be news to those who read of the "wettest place in the world" that Cherrapunji is generally stone dry. All the 400 or 500 inches of rain falls in a few months, and then generally at night. The rock is close to the surface and there is enough slope to ensure that the water runs off at once and pours over the 3,000 foot cliffs within a few hours.

BENGAL.

Bengal has large water-power in its Himalayan area, in the Teesta and its tributaries. So far as we know it has none within economic reach of the Calcutta industrial area, where coal is still cheap. Only quite recently has a small sum been provided to begin the survey in the Province.

BIHAR AND ORISSA.

In the neighbouring province of Bihar and Orissa there is not a great deal of power, and the investigations so far made have been very casual. The fact that the great coal fields are mostly in this area has, no doubt, been a factor; but coal is a wasting asset and will not last for ever, and its price has risen greatly of late.

MADRAS.

Madras is favourably situated in having two monsoons over a good deal of the Province. A small staff has been working there since the Survey commenced, but constant changes in personnel have not helped matters. A considerable amount of power has been located, but it will take several more years to examine all these sites. There is, however, a choice of several good sites within 80 to 100 miles of the new harbour, which is to be made at Vizagapatam; and the harbour without power or industries would not be likely to go far. I am glad to say that Sir Trevredyn Wynne is fully alive to this, as some of the local people seemed to think that the place would flourish on a few oil engines. Of these sites the Kolab River has been carefully examined and seems likely to yield some 18,000 e.h.p., while the Machkand River may be worth more.

It must be more than 20 years since the utilisation of the water of the Periyar Lake, which cascades down the hill over 1,000 feet, was first broached. It is still under discussion, I believe.

One of the most interesting sites found in Madras is known as the Pinjikave project, as there is a head of over 5,000 feet available. I was told when we began, by a high official, that there was no prospect of finding any high head schemes except in the Western Ghats. This Palni Hills project is not likely to prove cheap, as only about 6,000 e.h.p. can be obtained, but its interest lies in the fact that it utilises a pre-historic reservoir site, from which there can be little doubt that the water was once diverted from one catchment area to another. The old works were discovered in the sixties by an officer examining the Palni hills for a sanatorium, and the old papers were brought to light by Mr. Sneyd in 1919.

UNITED PROVINCES.

In the United Provinces, the Himalayas are beyond the border, in forbidden Nepal, except at the western end. Nevertheless, there are considerable possibilities awaiting development, amounting to about half a million e.h.p. In the area to the south of Allahabad and Cawnpore, there are a number of excellent sites, of which those on the Tons, Beehar and Ken Rivers are the finest. These are only 140 miles from the great industrial area of Cawnpore. A concession for the development of over 20,000 e.h.p. on two loops in the Jumna River was applied for about 17 years ago, and granted after a few years' consideration. Not a stone has so far been turned, although the site is within economic reach of the capital of India—Imperial Delhi. The Kosi is at about the same distance from Delhi and also has some 20,000 e.h.p. in prospect. A small scheme has recently been set to work at Naini Tal, under a head of 1,500 feet.

PUNJAB.

The Punjab has only recently begun a systematic survey, but it has been busy with the possibilities of the Sutlej River, where it enters the plains. By short-circuiting the great loop in the river, with a tunnel, it is estimated that 100,000 e.h.p. or more can be obtained on the lowest discharge. This site has been known to me for about 30 years, and no one knows who the original discoverer was. There appears to be ample room for all the power that can be obtained. At present a smaller subsidiary project is under construction for about 10,000 e.h.p., and it is to be hoped that the province will not rest content with this. The Himalayan area is certainly full of power, and the canal falls alone are in the aggregate good for 100,000 e.h.p.

BOMBAY.

Bombay is so well satisfied with its known power that the survey came to an abrupt end with the Reforms. Apart from existing plants and the Koyna project, the Kalinadi River scheme is the most promising; it is a long way south of these others and is estimated to be good for 45,000 e.h.p. The Kaneri River, the Sonda, the Tadri and the Bedti also have large possibilities only partly examined.

NORTH-WEST FRONTIER.

In the North-West Frontier Province there has been no survey, for the very good reason that it is too unsettled to devote itself to any industry but raiding. There is enormous power in the Himalayan area of the Indus, and if the area could be transferred to the United States it could and would be developed. At the same time the difficulties would be enormous unless the floods could be permanently regulated as they were, temporarily, when a landslip blocked the whole valley in Gilgit some 80 years ago. I have even made some rather hair-raising suggestions as to how this might be done, just to set people thinking; for regulation of this sort would be worth untold millions to the irrigation interests also. It is believed that about 35 per cent. of all the rainfall of the peninsula, exclusive of Assam and Eastern Bengal, is carried away to the sea (Indian Irrigation Commission, quoted by Buckley).

THE REST OF THE PENINSULA.

Of the central portion of India, comprising the Central Provinces, Central India and many Native States little need be said. Here and there a promising scheme has been brought to light and investigated, but the precarious nature of the rainfall and the absence of high ranges of hills are against us. A gentleman in the Indian Civil Service discovered a promising site within reach of the industrial city of Nagpur, and has written a score of pamphlets about it. He and I do not see eye to eye over it, but nevertheless this Silewani Ghat scheme seems to be the best in the neighbourhood. Mysore, however, may be classed with Madras, except for the fact that it has gone ahead, while the "Benighted Province" remains contemplative. Kashmir in the far north has developed one source of power but has failed to make any use of it. It has plenty more.

BURMA.

Burma has both mineral wealth and power in abundance, but it is hampered by lack of enterprise, lack of roads, and lack of funds for development. Considering the physical difficulties met with, the Survey has done wonders under my old friend and colleague, Mr. Raikes. At present Burma's industries depend mainly on rice husk and sawdust for fuel and power, and it is not easy to compete against these. The various mining concerns, however, have developed their own water power and, of course, the oil fields use their own product. There are sites on the Nam Pang, the Nam Tu, the Pan Laung and the Yunzalin River each good for some 30,000 to 40,000 e.h.p., and about 200,000 e.h.p. is located. The Yunzalin site is only about 100 miles from Rangoon, and the project has recently been presented to the Government. Of more speculative rivers the Schweli may have 300,000 e.h.p. at one site and the Salween 150,000 e.h.p. at Hatgyi rapids.

THE FUTURE.

The Survey, I fear, will peter out very soon. Its records will be useful to future generations, but the records most wanted are not in existence and are not being collected generally. I refer, of course, to stream gaugings. If these had been put in hand in 1905 we should have had 15 years of them to work on when we began, instead of none at all—except of course

in the case of irrigation rivers. The defects of the Land Acquisition Act and of the Companies Act have already been recently drawn attention to before another society, and I can only say that I agree with Mr. Arnall and Sir Thomas Holland in that matter.

During the discussion on Mr. Arnall's paper Dr. Crowley expressed a hope that an "Imperial Conference on Water-power" would be called, as suggested by the Water-Power Committee of the Conjoint Board of Scientific Societies. Why this has not been done long ago is a wonder to me, and I would also urge the necessity of it.

CONCLUSION.

In conclusion I think I may claim that in its inception the Hydro-Electric Survey of India is the largest investigation ever attempted in India, and even the incomplete results obtained will bear comparison with work on which ten times as many people have been engaged. For a long time there was not more than one European on the work in any one Province, and it was only in the later stages that the services of a considerable subordinate staff could be utilised. To all these men who did the work, to Sir Thomas Holland who initiated it, and to Mr. Barlow who organised it, great credit is due.

DISCUSSION.

THE CHAIRMAN (Sir Thomas H. Holland) said the author was not entirely correct in assuming that the Industrial Commission showed a touching faith in the omniscience of the Public Works Department. In the first place, the summary of the recommendations of the Commission published with its report, contained a misprint which might seem to reinforce that idea, but if one examined the full text of the report, paragraph 100, it would be found the Commission said that proposals for generating water-power from canal falls and other irrigation works should be considered by a joint committee composed of officers of the Public Works Department and Industries Department—not the Irrigation Department, as stated in the summary. It was not quite the whole story to say, moreover, that the Commission recommended that the Chief Engineer of the Public Works Department should undertake the survey. What they really said was that the survey should be placed under a Public Works officer, of the Rank of Chief Engineer, and that it would be necessary to associate with him an electrical adviser. It was said that the question of whether the Electrical Adviser to the Government of India should perform that office o ght to be considered. The Government of India accepted that recommendation, and he thou ht everyone would agree that their Electrical Adviser carried out his duties very well indeed. The Commission were quite aware, as stated in their report, that up to that time, prospecting for water-power had not been recognised as one of the essential duties of the Public Works or any other Department. The data which were obtained by a circular in 1905, and which the author had described in unflattering terms, were cast in a mould not unfamiliar to those who had attempted to obtain information by the agency of other departments in no way interested in the results. The returns were of the mechanical circular kind, compiled from reports by not over-intelligent but grossly overworked subordinates, who were bored—as they always were bored—by what they regarded as meaningless curiosity on the part of harmless but unpractical scientists. When those returns were brought before him, he put them aside as practically useless. Having had previous experience of answers of the circular order, he turned his attention to other matters, of which there seemed to be at that time quite enough to occupy him for the rest of his service as Director of the Geological Survey. The institution of the Industrial Commission, some 11 years later, offered an opportunity of reviewing the question afresh. The development of electro-metallurgical industries during the interval, and their vital importance for munitions, which was painfully evident to them in 1917, altered the whole question. It became obvious from the evidence placed before them by witnesses—the author and others—that the question of utili ing the water power of India would soon be forc d on the attention of those responsible for the well-being and safety of the country. In the first place, it was obvious that the coal deposits were being depleted to an extent which would give cause for real anxiety, especially in regard to the coal suitable for metallurgical operations, in the near future—possibly within the present generation. The main coal deposits of India contained a very large percentage of ash, and, consequently, a correspondingly low calorific value. They could not be worked to a depth comparable to the coal deposits of Great Britain. There was a depth—comparatively shallow—for coal of the kind in question from which it cost more to raise the coal than the coal would return afterwards i saleable power. In the second place, the exploitation of oil was proceeding at a rate well in excess of the increase in reserves by the discovery of new fields. Ordinary economic demands, therefore, would make the mineral fuel question in India a matter of serious concern even with the development only of those activities which required fuel as a motive force—for the mills, factories and transport services. If

anything appreciable took place in the development of metallurgical industries, a fuel crisis would be brought considerably nearer. In the third place, hydro-electric power was wanted, not only to mitigate the demand for mineral fuel; there were some industries of vital military necessity which could be undertaken only, or most suitably, with electric power at a relatively low cost. Unless such industries were taken up soon, the Indian patriotic leaders would discover that neither the reformed Councils nor the spinning wheel were of any defensive value. There was another consideration before the Commission. Imitation or, more correctly speaking, caricature of European Labour movements threatened the life of the coal industry in India more seriously than the mechanical difficulties of mining. That would be effective in diminishing results by alarming capital which would otherwise be laid out on low grade and new propositions, because of the menace which they afforded. There were many coal deposits which might not be developed at all on that account. Hydro-electric power had the great advantage of reducing the labour menace appreciably A striking illustration of that appeared in the papers that morning in a report of the speech of the Chairman of the English, Scottish and Australian Bank. Mr. Andrew Williamson, chairman of the Bank, in reviewing the industries of Australia, pointed out that, but for the wisdom of the Tasmanian Government in utilising their abundant natural water power, zinc smelting would have become as unremunerative as that of other metals, but, by the adoption of a new hydro-electrolytic process for zinc, the principal company in Tasmania had been able to carry on with only a fraction of the men required to run an ordinary zinc plant. The other metallurgical industries of Australia were rapidly succumbing to the demands of labour. The question of labour, therefore, was before the Commission, and helped them to realise the necessity of developing hydro-electric power. Then came the question of agriculture. Agriculture was, at the present time, and must always be, the most important industry in India. The importance of agriculture was the justification of the irrigation branch of the Public Works Department. The conflict between water-power as a fuel and water as a fertiliser was, therefore, brought into prominence and in that connexion technologists, such as the author, came into conflict with the irrigation officers. It seemed to him natural that irrigation officers should regard with some suspicion any innovation which might disturb the regularity of their operations for storage and distribution. The rules, regulations and controlling formulæ used by irrigation officers had been established by long experience, and the average irrigation officer hated with suspicious fear—he might almost say superstitious fear—anything that might conceivably disturb his delicately balanced equation of costs and revenue. Generally, the irrigation officer dealt with large bodies of water carried over wide areas with regard to which very slight differences of level might painfully demonstrate that his equation was what chemists called a reversible reaction. The sums involved in an irrigation project were so large that no one individual would undertake the responsibility for an innovation of the kind in question. The population depending on the accuracy of an irrigation officer's work was not only great, but, like the body of water itself, in a state of unstable equilibrium. He sympathised, therefore, with the tendency of irrigation officers to conservatism. He sympathised with them when they came into conflict with the enthusiasm of the electrical expert. It must be remembered that if the British, during the process of abdicating their trust—which was the way in which many people read the modern changes which were taking place—left nothing behind them in India but their irrigation works, they would have conferred a lasting benefit on the people of that country. In discussing the terms of their report, and in making the proposal to associate a chief engineer of the Public Works Department with experience of irrigation with the Electrical Adviser, the Commission had considerations of that sort before them. The proposal to put a Public Works officer in charge of the Hydro-Electric Survey might not satisfy the electrical enthusiast, but the Commission had to pay regard to things as they were, and frame their proposals with the knowledge that consideration of irrigation requirements must take precedence of mechanical power. It not only would take precedence, but in a country like India it ought to do so. Personally, he would rather see no manufacturing industries in India at all than reduce the agricultural efficiency of the country. There was room, however, for both, and even opportunity for cheap power to assist agriculture itself. He did not propose to take up the time of the meeting by reviewing the facts described in Chapter 5 of the Report of the Industrial Commission, where figures were given to show the amount of power of the "living machine" at present being utilised for the agricultural operations of India. It was estimated that cattle power alone accounted for something like five million horse-power, and there was also the enormous amount of manual labour performed by the ryot himself. There was any amount of room for the introduction of cheap power for the benefit of agriculture; in some cases by its direct application, where circumstances permitted, and in other cases by the replacing of fuel, and especially oil, which was used in numbers of small oil engines for well irrigation. It was possible, therefore, by a proper blending of those two authorities—the Electrical Adviser and the

irrigation officer—to discover some form of action that might be for the general and safe benefit of India as a whole. The author had stated that the hydro-electrical questions had, under the Reform Scheme, become a transferred provincial subject, instead of a central reserved one, and had suggested that that decision was more of a fluke than a result of careful consideration. He would like to point out, however, that the Commission regarded the proposal for a hydro-electric survey as a central subject for the care of the Government of India itself. They proposed that it should be placed under a Public Works officer, and they wished, as he had said, to associate with him the Electrical Adviser to the Government of India. The financial estimates were made on the assumption that there would be one chief engineer for the whole business, and not separate chief engineers for the hydro-electric survey in the separate provinces. The Commission thought they had very good reasons for that proposal. One of those reasons had not been mentioned by the author, but he thought Mr. Meares would agree with it; it was the necessity, in a survey of the kind in question, of organising the collection of data spread over many years, data not only with regard to the flow of established streams, but with regard to variations in rainfall that manifested themselves only after many years of survey. In the case of Canada and the United States, where water operations were under the control of special departments, it was laid down that a number of uniformly taken approximate estimates of flow, spread over many years, were to be regarded as far more valuable than very precise determinations taken over a short period only. That was one of the considerati ns they had in view in proposing that the subject of the hydro-electric survey should be a reserved and central subject. The report of the Commission was written before the Montagu-Chelmsford Report was issued. The Commission were unaware of the proposals of that report, which, moreover, left the distribution of subjects to be determined by a special committee sent out at the instance of Parliament. The classification into central and provincial, transferred and reserved subjects was made by that Committee. There was, however, something to be said for both sides. There were advantages in central control for the Hydro-Electric Survey, as the Commission had found, just as there were advantages in the case of the Geological Survey, but, on the other hand, the machinery to be employed was provincial, and it might be held that provincial officers of the Public Works Department were most capable of doing the work and most conveniently provided with the necessary staff and equipment. It was also, from a political point of view, desirable, possibly, that each province should be responsible for carrying out its own hydro-electric survey. He did not propose to pursue the point further, because it was far removed from the main points of the very interesting paper the author had presented.

MR. ALFRED DICKINSON, M.Inst.C.E., M.I.E.E., M.I.Mech.E., said the reports prepared by the author for the Government were exceedingly useful, although necessarily voluminous. The paper which had been read that afternoon crystallised them. His personal experience was that hydro-electrics in India required more careful investigation than similar undertakings in other countries. The author had rendered good service by emphasising the necessity for investigations extending over long periods. To instal a hydro-electric plant on one or two years' rain records or stream flow would be unwise; the results might be very unsatisfactory, particularly in those cases where the water power supplied was not from perennial flow, but largely from stored water. The Tata hydro-electric installation was founded primarily upon the records kept by the G.I.P. Railway, one at Lonaula and one at Bushi, over a period of 37 years. Being satisfied that those rain gauges showed the rainfall essential, the late Mr. R. B. Joyner and himself selected sites for the lakes and had a large number of rain gauges placed over the area selected and readings taken over several years. The results of those records were compared with those of the G.I.P. Railway taken over the same period, and in that way the value of the latter records was checked. Next, the Bombay Government had to be convinced that it was a sound engineering proposition. That having been done, the objections of three very important bodies, the Bombay Municipality, the Bombay Light and Power Company, and the G.I.P. Railway, had to be met. The procedure adopted by the first promoters of railways in this country had, therefore, to be employed. It was well known that the original railways in England often had to be diverted to meet the objections of landowners and municipalities. At that time it was not possible to secure the best scheme; he, therefore, had to select one which offered the path of least resistance. Valuable assistance was given by the Department over which the author presided. He assumed the author would agree that the Government reports were to be taken as indications of where closer investigation was justified. The paper reminded him of the old saying that there was nothing new under the sun. In 1905 he was satisfied that there was great opportunity for possible development of hydro-electric power in India; he, therefore, suggested the desirability of a hydro-electric survey of the whole of that country. For a long time he had laboured under the belief that it was he who had induced the Indian authorities to undertake such a survey. He was, however, more than pleased

to know that he had been anticipated by a very "live wire" in all such matters, Sir Thomas Holland. He was satisfied that there were a large number of commercially possible schemes in India. He himself had two schemes, both of which had been authorised by the Government of Madras. The difficulty of fructifying schemes was largely due to the want of appreciation shown by the financiers and manufacturers of this country of the possibilities of Indian industrial development. For example, the whole of India was open to the cotton manufacturers of Lancashire. Indians were prepared to enter into partnership or working arrangements with textile manufacturers in Lancashire for the establishment of cotton mills in India. The Lancashire men, however, would not adopt such opportunities, but preferred to take exceptions to the tariffs imposed by the Indian authorities against cotton fabrics, not realising that it was the avowed policy of the Indian authorities to encourage Indian industrial development by protection. The Home authorities would not interfere with such a procedure, and unless British manufacturers established industries for their own particular products in India, they might lose their Indian markets. The question of payment of interest during construction was a two-edged sword. In his judgment, it should remain in the hands of the Government to authorise or disallow such payment. He had found that the Government were perfectly reasonable upon the point. In the main he agreed with the author that a payment of royalties to the Government was not conducive to hydro-electric development, being a charge on production and, therefore, increasing the price of power. Government revenue would largely benefit in other ways—income tax, tariffs on imported plant and so on. Being responsible for the installation of the first commercial hydro-electric undertaking in India, he was naturally much interested in hydro-electric development. He thought, however, it was only right to issue a note of warning. Unless a hydro-electric scheme could be established to produce and sell energy at a lower rate than was possible by any other form of power, it was not justifiable. Some people compared the working costs of a hydro-electric plant with those of a steam plant. The former on that basis showed enormous advantages, but were the interest on the hydraulic development added to the working costs, those advantages would disappear. It must never be lost sight of that interest on capital for hydraulic development was really a charge comparable to that for fuel in a steam station.

Sir Louis W. Dane, G.C.I.E., C.S.I., regretted he was not in India when the author started his electric survey, because probably he might, as one of the oldest inhabitants, have been useful to him; he knew something about previous enquiries into the hydro-electric question. The high price of coal, which rose Rs. 5 a ton at the pit head in Bengal to from Rs. 30 to 40 at Lahore, made industries in the Punjab practically impossible. The policy of the authorities had been to secure the land-owning classes in possession of their land, and that prevented, to some extent, the commercial classes from obtaining an outlet for their energies in the acquisition and use of land. He had been attracted by the possibility of obtaining hydro-electric power from the great rivers of the province, and as far back as 1896 had agitated for its utilisation. At that time, no one would take him seriously. People said: "There are no industries, and, therefore, you do not want power." He had replied: "That is a vicious circle. You cannot have industries because you have not got power." He had also tried to develop the coal and oil resources of the country. Little success was obtained with regard to coal, though the N.W. Railway were again using the Punjab and Jamu coal, but oil had been found and was being exploited by a Company, to which he wished all success. In 1897, he first suggested the employment of the power obtained from a stream in the valley below Simla for pumping and lighting the town, and also, possibly, for the railway. After many enquiries he had been able to get the work carried out, when Lieutenant-Governor of the province, in 1913, and further extensions were now in progress. There was also the possibility of utilising the large irrigation reservoirs where the big rivers left the hills. He got his engineers to go with him and see the various possible sites. One of these big schemes, the Bhakra Dam, had now been taken up, and he hoped would be carried through. When he reported four of those schemes to the authorities, he was told he must take no credit whatever for any return obtained from hydro-electric power; the schemes must be made to pay entirely from the irrigation aspect. However, he had been able to show that the Bhakra scheme would pay 7 per cent. on the irrigation aspect alone; it would irrigate 2,000,000 more acres than before, and probably about 150,000 H.P. would be made available by a tunnel through a point on the range as he suggested. There were some advantages, therefore, in a ubiquitous revenue officer who did not know much about engineering, but who got his engineers to help him in carrying out ideas. Owing to the enormous increase in the wealth of the Punjab, due to the irrigation canals, it had absorbed for over twelve years about £4,000,000 a year in sovereigns. The people found it difficult to employ that money, because no outlet had been opened up for the energies of the commercial and educated classes. He looked forward to a great industrial movement in the Punjab in the near future; if it came, it would depend largely on hydro-electric power. At the same time, it would largely

solve the political problem in that province. When appointed Resident in Kashmir, he was able to set on foot schemes for employing the water-power of the district. In one case, 20,000 H.P. was made available, only 5,000 of which was utilised for the State silk filatures, lighting, etc., in Sainagar; the difficulty about it was that it involved a transmission line to the Punjab, 160 miles in length. This or the fall on the Upper Swat Canal at the Malakand, which could produce 15,000 H.P., and was due to a suggestion made by him in 1904, might have met the war demand for power for munitions. Perhaps the long transmission line in one case, and its vicinity to the frontier in the other, prevented their being so utilised. He could assure the meeting that there was an immense future in India, even under existing conditions, for hydro-electric power.

Mr. D. T. Keymer said that after the policy of doing nothing which had been mentioned by the author as prevailing in the rest of India, he thought it would be interesting to state what was being done in the little kingdom of Nepal. In 1910, the present Maharaja, H. H. Sir Chandra Shum Shere Jung, arranged for the installation of a hydro-electric scheme. The water was brought down 700 ft. through a 20in. pipe, and about 700 H.P. used. A further development was now taking place. The Nepal Valley was shut off from the Terai by two great spurs from 10,000 to 12,000 ft. high, and very precipitous. The Maharaja had arranged for an extra unit of hydro-electric power to be installed so as to work an aerial rope way which he was having constructed over those spurs. The power plant was now being sent out, and the Engineer to the Nepal Government, who had the work in hand, had the pleasure of being present at that meeting. Such an example of enterprise should, the speaker thought, be recorded.

Dr. J. F. Crowley, M.I.E.E., said it ought to be very clearly recognised that the hydrometric survey was only one of the many things which India owed to the foresight of Sir Thomas Holland. It was, of course, very much to be regretted that in the opinion of the author of the paper the work of the survey had ended for the time being. With regard to the results of the survey, the author seemed to be satisfied that from 7,000,000 to 8,000,000 H.P. was available. If that was taken at a load factor of $33\frac{1}{3}$ per cent., which was a usual industrial load factor, little short of 26,000,000 H.P. would be found to be available for ordinary industrial purposes. The H.P. at present in use in the United Kingdom for all industrial purposes was only 13,000,000; that in use over the Continent of Europe, excluding this country, 24,000,000 That gave some idea of the high value to be attached to the water-power resources of India. There were, however, many difficulties in its employment. In the case of the Tata scheme, the whole of the water to be used throughout the year had to be stored during a monsoon lasting only three or four months. Again, some of the sites were very remote from industrial centres; those on the Himalayas, to which reference had been made, were many hundreds of miles from the important industrial centres in the south. Developments had taken place, however, during recent years in electro-chemical work and electrical work also, which made the development of power sites of the character in question more profitable to-day than they had been, perhaps, for many years. Schemes had been worked out which would enable intermittent power to be used to an extent hitherto undreamed of. One might safely say that the recent developments in connexion with nitrogen went further towards solving the intermittent power problem than anything which had been done previously There was a further development which made the employment of water-power more profitable to-day than in years past. Long distance electrical transmission had been developed enormously of late. When the Tata hydro-electric scheme was projected, 100,000 volts was regarded as a remarkably high voltage, as, indeed, it was at that time. There were schemes under consideration to-day, however, which involved power transmission at 220,000 volts over distances of 250 miles and over, and such schemes were perfectly practical propositions provided the cost of power justified the cost of the transmission lines. As a result of the war, and owing to the work of the Water Resources Committee, British manufacturers had shown commendable enterprise of late in regard to hydro-electric matters. It was no longer necessary to-day to go outside the Empire for material for the pipe lines, hydraulic and electrical machinery, and so on; the whole of the work could be done by big British corporations, which had laid themselves out for the purpose, and their work compared favourably with that done on the Continent and in America. It was painful for a British engineer visiting India to find so many schemes with plant which did not come from the home country, and it was pleasant to know that that condition of things need no longer apply. He would like in conclusion, to add his tribute to the many given to the work of the Public Works Department of India. One of the reasons why he was strongly in favour of an Imperial Conference being held was that the work of the Public Works Departments in Egypt and India could thus be made available for home engineers, and vice versa. If, as a result of the paper some effort could be made to continue the hydrometric survey of India, it would be a very good thing. He spoke as one to whom the first, second and triennial reports had proved of considerable value, and he, in common with many others, would like to see the survey carried to a reasonable completion.

Mr. Arthur T. Arnall, M.Inst.C.E., said Great Britain should fully realise how immense were the water-power resources of India, and India should realise how important it was to develop those resources. Indian industries at the present time found employment for about $1\frac{1}{2}$ million people out of a total population of 226,000,000. They were, therefore, of much less importance than agriculture, but were of great financial importance in themselves, and their development was an essential factor in India's political future. Agriculture by itself would never enable India to manage her own affairs or rely on her own resources, or to attain her rightful place in the world. Agriculture must be supplemented by industrial development. Owing to the abundance of water-power available and the comparative scarcity of coal, water power would play no small part in that development. The author had referred to a paper which he (the speaker) had read before the East India Association. Unfortunately, it was read before he received the third report of the survey. He would like to reply to one point raised by the author. He feared he was responsible for the statement quoted by the author, that in a few years all essential information for the development of India's water-power resources should be available in a concise form for general use. When he said that, he did not know that the Government of India would stop the survey before it was completed. What he anticipated would be done was something on the following lines. As was well-known, the daily rainfall was recorded by local Governments at about 2,000 stations distributed throughout India. In addition, gauges were kept by the railway companies, tea gardens and other private concerns. The greater part of those records were for parts of the country of no interest to water-power engineers, and few or no records were available in water-power districts. What appeared desirable was to choose from the power sites disclosed by the survey those that were most likely to be of value in the near future, to compile into one volume all existing rainfall and river gauging statistics relative to those sites, and to establish additional rain and river gauges where desirable. It was information compiled on those lines which he had hoped would be available in a few years' time. Such information was most essential. The expenditure incurred, which would not be great, could be recovered from those taking up concessions. The procedure he had outlined might be started in a small way, and, as time went on, the more remote power areas included.

Dr. J. A. Harker, O.B.E., F.R.S., said that during the last year a great advance had been made with a new nitrogen fixation process, which seemed to be of very considerable importance for remote water-power schemes in a predominantly agricultural country, where a local supply of cheap fertilisers was important. The chief difference between the new process to which he referred and those formerly employed was, that in the new method cheap water-power was practically the only *sine qua non*. No raw materials other than water and air and hydro-electric power were required for manufacture of the initial product, which was liquid ammonia. It appeared practically certain from the costs of working already attained, that ammonia could be produced by the new method at a price very much lower than by any other process hitherto employed.

The Chairman said that with reference to Dr. Harker's remarks, one had to be extremely careful about urging the development of nitrogen fertilisers in India. In Behar, at any rate, near the tropical line, nitrifying bacteria produced nitrate of potash in the soil to such an extent that it was exported to an extent of nearly 20,000 tons a year. One should not go out of one's way, therefore, to manufacture an article which nature already provided in excess.

Mr. Frank Noyce, I.C.S. (Indian Trade Commissioner), in moving a cordial vote of thanks to the author, said the fact that local Councils did not vote funds for the continuance of the survey ought not to be put down to any desire on their part not to disturb "the placid, pathetic contentment" of the masses of India. There were two reasons why they had not shown themselves more favourable towards the survey. The first and most important was that they had not got the money; anyone who read the Indian papers knew that the Provincial Governments were at their wits' end to know how to raise funds. The second reason was ignorance. The Ministers and new Councils needed education on the possible results of hydro-electric installations. Whether the new Ministers were worse than the old Members in that respect, the author could probably judge better than himself. At any rate, there had been one Member who possessed far more knowledge of the possibilities of such work than the others, and the meeting was fortunate in having him in the chair that day.

Mr. Sidney Preston, C.I.E., C.B.E., in seconding the motion, said he happened to be Secretary to the Government of India at the time when the first Electricity Bill was introduced. Being absolutely ignorant of electrical affairs at that time, he was entirely dependent on Mr. Meares. The latter said that the Electricity Bill had been revised twice. Personally, he was not surprised at that, because with the one exception of the author himself, no one else in India knew anything about electricity on a large scale.

The Chairman said that before putting the motion he would like to assure Mr. Preston that the necessity for revising the Electricity Act was not in any way due to its original imperfections; the changes that were made were due entirely to the progress which had occurred in the interval, especially in the development of electricity for motive power.

The motion was carried unanimously.

Mr. Meares, in his reply, said he did not mean to be unfair to Sir Thomas Holland and the Industrial Commission in his remarks about the survey, although he had to take objection to the attitude of the Public Works Department, who did not themselves know how to do it and who would not give other people a free hand. He agreed with Mr. Dickinson that capital cost was the essence of the question in hydro-electric work. India owed a great debt to Sir Louis Dane for all he did; sometimes his engineers were a little worried over the innumerable schemes he threw at them while Lieutenant-Governor of the Punjab, but it did them a great deal of good. He had omitted mention of the work done in Nepal in his paper, because that was an independent kingdom and not under the control of the Central Government. Dr. Crowley, whose experience of such matters in connexion with British investigations was very great, had raised an important point with regard to non-continuous power. There were incalculable possibilities during the five or six months of the monsoon in India; if the power available during the months of the monsoon was taken the figures given in his report would have to be multiplied by anything between six and twelve. He agreed with Dr. Crowley that nowadays British manufacturers were fully capable of undertaking any work necessary in connexion with hydro-electric plant, but, unfortunately, they had started rather late in the day. With regard to rainfall, as had been mentioned, very many rain gauges existed, but only on the rarest occasions were the data thus obtained of the slightest use, owing to the unsuitability of the sites.

The meeting then terminated.

CORRESPONDENCE.

IRRIGATION ENTERPRISE IN INDIA.

In the *Journal* of September 8th, 1922, Mr. F. W. Woods, C.I.E., in his paper on "Irrigation Enterprise in India," has a paragraph, No. 38, headed "Views of the Hon. Mr. H. S. Lawrence." Mr. Woods has given what purports to be a quotation *verbatim* of certain remarks of mine on the Sukkur Barrage Project. These remarks were available to Mr. Woods for verification, having been printed as Appendix D on pp. 114-5 of Volume II. of the publication known as the Sukkur Barrage Project, 1919. The quotation is defective in four important points:

(*a*) It does not reproduce the exact words;

(*b*) It cuts out sentences in different paragraphs and pieces them together;

(*c*) It substitutes "tons (of food and cotton)" where I wrote "lakhs of acres"; and

(*d*) It omits to note that these remarks were written in January, 1919, with reference to a preliminary stage of the project and have no application to the figures of the final Project.

2. I subjoin the principal misquotation:—

Mr. Woods quotes as follows:—

> "These canals are estimated to supply water for an annual cultivation of 2,700,000 tons (of food and cotton). Of these 2,700,000 tons, 900,000 would be on lands at present wholly uncultivated, and on lands already cultivated 900,000 tons would be rendered secure and another 900,000 tons would be new cultivation."

I actually wrote as follows:—

> "These canals are estimated to supply water for the annual cultivation of:—
>
> (a) On the Right Bank:
> 6 lakhs of acres of Rice
>
> (b) On the Left Bank:
> 3 lakhs of acres of Jowari
> 4 ,, ,, Cotton
> 10 ,, ,, Wheat
> 4 ,, ,, Pulses
>
> 27 lakhs of acres.
>
> "Of these 27 lakhs of acres of cultivation, 9 lakhs are lands at present wholly uncultivated; thus on 18 lakhs of acres of old cultivation the crops would be made secure and 9 lakhs of acres of new cultivation would be added."

3. In paragraph 23 of Mr. Woods's lecture, it is stated that the Sukkur Barrage Project aims at irrigating annually an area of 5,300,000 acres; whereas my remarks referred specifically to an area of 2,700,000 acres, or one-half of the area covered by the Final Project.

4. Mr. Woods proceeded to attack the accuracy of my prediction that the value of the crops, then still unharvested, would be £3,500,000, by quoting a valuation made a year later that the value of the crops of *all Sind* had been £5,600,000. Mr. Woods omitted to notice that my estimate referred specifically to an area of 1,200,000 acres, which was all that was cultivated in that year, 1918, in the part of Sind then under discussion, while the subsequent valuation referred to an area of 2,600,000 acres in the whole of Sind.

5. Mr. Woods further accuses me of ignorance that the area irrigated by the perennial canals of the Punjab was one million acres less in 1918-19 than in the following year, 1919-20, and so on. As I was writing in January, 1919, I admit that I was not then aware of what was about to take place in the following year.

6. I am not concerned at the present time with the value of the criticisms by Mr. Woods of the Sukkur Barrage Project, but I think it is due to the readers of your valuable journal

to point out these serious errors in regard to time and place, in regard to accurate quotation and accurate mathematical calculation.

H. S. Lawrence.

19, Queen's Gardens, Poona (India),
October 25th, 1922.

Mr. Woods has seen the above and writes as follows :—

The substitution of the word "tons" for "acres," in the passage described by Mr. Lawrence as my "principal misquotation," was due to a typist's error, which, I regret to say, escaped my notice on proof-reading. The same may be said of the substitution of the figure "18" for "9" at the end of the same passage; for I find the correct version of the quotation in the manuscript which I copied from Mr. Lawrence's note. These errors, though regrettable, do not affect the soundness of my comments on Mr. Lawrence's note of January, 1919; but I agree that he is entitled to complain of them; and I thank him for pointing them out.

As regards his complaint of my omission to reproduce his detailed estimates of areas under rice, jowari, cotton, etc., totalling up to 2,700,000 acres, Mr. Lawrence should bear in mind that my duty to the distinguished Society I was addressing required me to study brevity in my quotation from his note. I would ask him to bear in mind that my quotation was, so far as it went, almost an exact reproduction of his words, and that whilst I allowed 36 lines to the quotation, I contented myself with only 27 lines of comment thereon. Expressed briefly, Mr. Lawrence's argument was that the Barrage Project was designed to irrigate annually an area of 2,700,000 acres; of which 1,800,000 acres was already irrigated annually, as a rule, by the existing inundation canals. During the year 1918-19, however, owing to low water-levels in the river Indus, the existing canals had irrigated only 1,200,000 acres.

The irrigation of barrage-controlled perennial canals was thought to be free from the drawbacks that affect inundation canals; so that, if the Sukkur Barrage were constructed, an irrigation of 2,700,000 acres could be relied upon every year: and the value of its harvest would be 2,700,000 x £5 = £13,500,000.

The irrigation of the existing canals would be worth only 1,200,000 x £3 = £3,500,000 (*sic*); so that the net advantage of the Barrage would be £10,000,000 in one year. And that was just what the Barrage Project was estimated to cost. My comment on this was that perennial canals also had their bad years; and I referred to the Punjab Canals by way of example. In appraising the financial value of existing canals he should have taken their *average* area of irrigation, viz., 1,800,000 acres, which, at £3 per acre, would have yielded a harvest value of £5,400,000, instead of £3,500,000, as calculdate by him. If he preferred to appraise on "worst-year" data, he should have reckoned also on the possibility that in a bad year the barrage might irrigate not more than, say, 2,000,000 acres. And he should not have ignored the influence of the great influenza epidemic of 1918-19 on the irrigation of that year.

Mr. Lawrence complains that I have ignored the fact that he wrote his note in January, 1919, and that it had no application to the figures of the final Project. To this I would reply that the report of the final Project passed through his hands in 1920, yet there is no record in it of any revision or correction of his note. And the Government of India, in a semi-official communiqué that was published in the *Pioneer* in September, 1921, wrote as follows, obviously in reliance on the applicability of Mr. Lawrence's note to the final Project :—

"The almost complete failure of the inundation in 1918 showed the extent to which disaster may be caused by the absence of control over the river . . . *a million acres* (my italics) went out of cultivation altogether. . . . . It is estimated that a loss to the countryside of no less than £10,000,000, or more than twice the cost of the Barrage, was incurred thereby."

But for this reproduction in the year 1921 of Mr. Lawrence's argument, it is probable that I would not have considered it necessary to make even a passing reference, in my lecture to his Note of January, 1919.

Mr. Lawrence remarks that he is not at present concerned with the value of my criticisms of the Sukkur Barrage Project. May I hope, however, that he is as willing to take professional advice on the subject as he was five years ago?

F. W. Woods.

GENERAL NOTES

Victoria and Albert Museum. — The Victoria and Albert Museum has recently acquired a very valuable collection of decorative wood-carving, numbering upwards of 350 examples, which was formed during the course of many years by Sir Charles Allom and has now been presented by him and Lady Allom, as a memorial of their son, Lieutenant Cedric Allom, Royal Field Artillery, who died of wounds at Ypres on the 20th October, 1917. The collection includes a considerable variety of panels and portions of panels, frames of doorways and windows, pilasters, capitals and other details of decoration; many of them showing indications of the original gold or colour. It ranges in date from the Gothic period to the end of the 18th century; and, though the predominant styles are French of the times of Louis XIV and the Regency, later French work is well represented as well as English decoration of the 17th and

18th centuries. In many cases, types hitherto unrepresented in the Museum collections are now made available; and, as a whole, this generous gift furnishes far more than the nucleus of an index to the study of the art of decorative wood-carving during the periods covered; and, for this reason, will be of the greatest value to students and craftsmen.

INDIAN BRICK-MAKING ENTERPRISE.—An enterprise of the Bengal-Nagpur Railway which is likely to have far-reaching effects on the building trade, is its efforts to manufacture bricks of a quality at present unobtainable in India. The company is investing 12¼ lakhs of rupees in a modern brick factory, which is to be erected at Gokalpur, near Khargpur. This factory will be equipped with devices which have been patented by Mr. Colquhoun, who is in charge of the works. Power for the factory will be taken from the Khargpur electric power house. The factory will employ 62 men and produce 150 lakhs of bricks annually, of the type known as engineering bricks. It is claimed that bricks known in the building trade as "first class bricks," can be manufactured in the factory at three to four rupees per thousand cheaper than the prevailing market rates.

THE RATTAN TRADE OF SINGAPORE.—The district of Singapore not only produces large quantities of rattan but is a big importer, buying 34,000 tons in 1920 and 26,000 tons in 1921. Most of these purchases were made in the Dutch East Indies. According to the United States Vice Consul at Singapore, the rattan coming into that port, either from the local field or from outside, is bought by European and American houses for export to their respective countries. In 1920 American dealers purchased 6,480 tons of rattan at Singapore, valued at $1,362,000. A large proportion of the American purchases are shipped to the Pacific ports and thence via rail to the furniture factories in Michigan. The cargoes intended for Atlantic seaports go to New York or Boston for the chair manufacturers in New England.

PRODUCTION OF LIGNITE AND BRIQUETTES IN GERMANY.—The production of lignite in Germany during 1921, as reported by the German Lignite Industrial Union, amounted to 123,000,000 metric tons, an increase of 10 per cent. as compared with the preceding year. Out of this total, 84,000,000 tons, or about 69 per cent., were produced on the Union's holdings. The production of briquettes in Germany during 1921 amounted to 28,300,000 tons. The Union's plants claim to have produced 19,900,000 of this amount, or about 70 per cent. The reasons given for the increased production, writes the United States Commercial Attaché in Berlin, are (1) a better technical state of repair of the mines and plants, and (2) an increased production per unit of labour.

MEETINGS OF THE SOCIETY.

ORDINARY MEETINGS.

Wednesday evenings, at 8 p.m.:—

JANUARY 17.—C. A. KLEIN, "Hygienic Methods in Painting—the damp Rubbing-down Process." THOMAS MORISON LEGGE C.B.E., M.D., D.P.H., H.M. Medical Inspector of Factories, will preside.

JANUARY 24.—SIR WILLIAM HENRY BRAGG, K.B.E., M.A., D.Sc., F.R.S., Quain Professor of Physics, University of London, "The New Methods of Crystal Analysis, and their Bearing on Pure and Applied Science." ALAN A. CAMPBELL SWINTON, F.R.S., late Chairman of the Council, will preside.

JANUARY 31.—THOMAS H. FAIRBROTHER M.Sc., F.I.C., and ARNOLD RENSHAW, M.D., D.P.H., "The relation between Chemical Constitution and Antiseptic Action in the Coal Tar Dyes."

FEBRUARY 7.—CHARLES R. DARLING, F.Inst.P., A.R.C.Sc.I., "Electrical Resistance Furnaces and their Uses."

FEBRUARY 14.—W. J. REES, Lecturer on Refractories in the University of Sheffield, "Progress in the Manufacture of Refractories."

FEBRUARY 21.—C. AINSWORTH MITCHELL, M.A., F.I.C., "Handwriting and its value as Evidence." SIR RICHARD D. MUIR will preside.

FEBRUARY 28.—PROFESSOR W. E. S. TURNER, D.Sc., Head of Department of Glass Technology, The University, Sheffield, "Heat Resisting Glasses."

MARCH 7.—

MARCH 14.—SIR WILLIAM WARRENDER MACKENZIE, K.B.E., K.C., President of the Industrial Court, "Industrial Arbitration." LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, will preside.

INDIAN SECTION.

Friday afternoons at 4.30 o'clock.

JANUARY 19.—THE EARL OF RONALDSHAY, G.C.I.E., late Governor of Bengal, "A Clash of Ideals as a Source of Indian Unrest." The RIGHT HON. VISCOUNT PEEL, G.B.E., Secretary of State for India, will preside.

FEBRUARY 16.—J. T. MARTEN, I.C.S., M.A., Imperial Census Commissioner in India, "The Indian Census, 1921." SIR EDWARD A. GAIT, K.C.S.I., C.I.E., Member of the India Council, will preside.

MARCH 16.—Lieut.-Col. SIR LEONARD ROGERS, C.I.E., F.R.S., F.R.C.P., F.R.C.S.,

Physician and Lecturer, London School of Tropical Medicine, "Recent Advances towards the Solution of the Leprosy Problem."

MAY 11.—

JUNE 1.—JOHN CAMPBELL, O.B.E., I.C.S. (retired), "The Indian and Burmese Sections of the British Empire Exhibition, 1924."

DOMINIONS AND COLONIES SECTION.

FEBRUARY 6.—SIR RICHARD A. S. REDMAYNE, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S., "The Base Metal Resources of the British Empire."

MAY 1.—L. GUY RADCLIFFE, M.Sc. (Tech.), F.I.C., "The Essential Oils of the British Empire."

Dates to be hereafter announced:

WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Recent Developments in Surface Combustion."

ARTHUR W. REEVES, M.I.Mech.E., M.Inst. Auto. Eng., "Motor Railway Coaches."

MAURICE DRAKE, "The Development of Mediæval Technique in Stained Glass Windows."

EDWARD PARNELL, "The Resources and Trade of Sarawak."

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

HENRY P. STEVENS, M.A., Ph.D., F.I.C., "The Vulcanisation of Rubber." Three Lectures. February 5, 12, 19.

J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards, "Length Measurement." Three Lectures. March 5, 12, 19.

SAMUEL A. DAVIES, Chemical Department, Messrs. Rowntree & Co., York, "Cocoa and Chocolate." Three Lectures. April 9, 16, 23.

HOWARD LECTURES.

Monday evenings at 8 o'clock.

STANLEY S. COOK, "Recent Improvement in Steam Turbines." Three Lectures. April 30. May 7, 14.

DR. MANN JUVENILE LECTURES.

Wednesday Afternoons, at 3 o'clock.

CHARLES R. DARLING, A.R.C.Sc.I., F.I.C., "The Spectrum, its Colours, Lines and Invisible Parts, and Some of its Industrial Applications." Two Lectures. January 3 and 10, 1923.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, DECEMBER 18 .. British Architects, Royal Institute, 9, Conduit Street, W., 8 p.m. Mr. A. N. C. Shelley, "The Law of Building Outside London."

Geographical Society, Lowther Lodge, Kensington, Gore, W., 5 p.m., Colonel Sir Gerald Lenox-Conyngham, "A Proposed Revision of the World's Longitude by Wireless Time Signals."

University of London, at the Royal College of Surgeons, Lincoln's Inn Fields, W.C., 4 p.m. Mr. V. W. Twort, "The Nature of Ultra-Microscopic Viruses" (Lecture IV.)

Mechanical Engineers, Institution of (Graduates' Section), Storey's Gate, S.W., 7 p.m. Mr. A. J. Gould, "Warships."

Victoria League, 22, Eccleston Square, S.W., 5 p.m. Hon. Gertrude Kinnear, "Personal Impressions of India."

TUESDAY, DECEMBER 19 .. Statistical Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.15 p.m.

Transport, Institute of, at the Institution of Electrical Engineers, Victoria Embankment, W.C., 5.30 p.m. Mr. W. H. Breach, "The Work of the Aire and Calder Navigators."

Civil Engineers, Institution of, Great George Street, S.W., 6 p.m. "Extensions at Tilbury Docks, 1912-1917," Mr. M. G. Du-Plat-Taylor.

Anthropological Institute, 50, Great Russell Street, W.C., 8.15 p.m. Dr. C. Fox, "The Distribution of Population in the Cambridge Region in Early Times, with special reference to the Bronze Age."

Colonial Institute, Hotel Victoria, Northumberland Avenue, W.C., 4 p.m. Mr. E. T. Fisk, "Wireless Service between Australia and Great Britain."

Swiney Lectures at the Imperial College of Science, Exhibition Road, South Kensington, S.W., 5.30 p.m. Professor T. J. Jehu, "Fossils and What They Teach" (Lecture IV.)

Chemical Industry, Society of (Local Section), The University, Birmingham. Mr. A. E. Tucker, "Metal Colouring."

University of London, at the Royal College of Surgeons, Lincoln's Inn Fields, W.C., 4 p.m. Mr. F. W. Twort, "The Nature of Ultra-Microscopic Viruses" (Lecture V.)

WEDNESDAY, DECEMBER 20 ... Geological Society, Burlington House, Piccadilly, W., 5.30 p.m. Professor O. T. Jones, "The Crystallization of a Doubly-Refracting Liquid." W. A. Richardson, "A Micrometric Study of the St. Austell Granite (Cornwall)." W. G. Shannon, "The Petrography and Correlation of the Igneous Rocks of the Torquay Promontory."

Industrial League and Council, Caxton Hall, Westminster, S.W., 7.30 p.m. Mr. J. Sexton, "Can Industry be Divorced from Politics?"

Microscopical Society, 20, Hanover Square, W., 8 p.m. Mr. J. E. Barnard, "Sub-Bacteria."

Meteorological Society, 49, Cromwell Road, S.W., 5 p.m.

THURSDAY, DECEMBER 21 .. Chemical Society, Burlington House, Piccadilly, W., 8 p.m.

Mining and Metallurgy, at the Geological Society, Burlington House, Piccadilly W., 5.30 p.m.

Mechanical Engineers (North Western Branch), Memorial Hall, Albert Square, Manchester, 7 p.m.

Swiney Lectures, at the Imperial College of Science, South Kensington, S.W., 5.30 p.m. Professor T. J. Jehu, "Fossils and What They Teach" (Lecture V.)

FRIDAY, DECEMBER 22 .. Swiney Lectures, at the Imperial College of Science, South Kensington, S.W., 5.30 p.m. Professor T. J. Jehu, "Fossils and What They Teach" (Lecture VI.)

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FRIDAY, DECEMBER 22, 1922.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, ***W.C.*** **(2)**

NOTICES.

COUNCIL.

On Monday, December 11th, the Council elected SIR ROBERT ABBOTT HADFIELD, Bt., D.Sc., F.R.S., a member of the Council to fill the vacancy caused by the retirement of MAJOR PERCY A. MACMAHON, R.A., LL.D., Sc.D., F.R.S.

SIXTH ORDINARY MEETING.

WEDNESDAY. DECEMBER 13th, 1922; THE EARL OF CRAWFORD AND BALCARRES, K.T., P.C., F.S.A,, in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Bruford, Stanley John, Nepal.
Parker, William Rushton, M.A., M.D., London.
Wright, Frank Claude, A.M.I.Mech.E., London.

The following candidates were duly elected Fellows of the Society:—

Carmichael, Harry Tucker, Kentucky, U.S.A.
Christie-David, Clement Harold, Colombo.
Johnson, George, Leigh-on-Sea.
Nutt, Ernest S., Sheffield.
Patterson, Thomas Hamilton Hoge, Philadelphia, U.S.A.
Starr, Nathan Comfort, Maryland, U.S.A.
Swift, George, J.P., Pershore, Worcester.
Vardy, Rev. Reuben, Ripon, Yorks.
Varman, Thakur Gopi Nath Sinha, B.A., Bariellv, U.P., India.

A paper on "The Loss of Colour in Objects exposed to Light," was read by SIR SIDNEY F. HARMER, K.B.E., Sc.D., F.R.S., Director of the British Museum of Natural History.

INDIAN SECTION.

FRIDAY, DECEMBER 15TH, 1922; SIR EDWARD R. HENRY, Bt., G.C.V.O., K.C.B., Inspector-General of Police, Bengal, 1891; Commissioner of Police in the Metropolis, 1903-18, in the Chair.

A paper on "The Settlements of Criminal Tribes in India," was read by COMMISSIONER F. DE L. BOOTH TUCKER, I.C.S., retd., Salvation Army.

The paper and discussion will be published in a subsequent number of the *Journal.*

MANN JUVENILE LECTURES.

Under the Mann Trust a short course of lectures adapted to a juvenile audience will be delivered on Wednesday afternoons, 3rd and 10th January, 1923, at 3 p.m., by Mr. Charles R. Darling, F.Inst.P., F.I.C., on "The Spectrum, its Colours, Lines, and Invisible Parts, and some of its Industrial Applications." The lectures will be illustrated with experiments.

Special tickets are required for these lectures. A sufficient number to fill the room will be issued to Fellows in the order in which applications are received, and the issue will then be discontinued. Subject to these conditions, each Fellow is entitled to a ticket admitting two children and one adult. Fellows who desire tickets are requested to apply to the Secretary at once.

REPRINT OF CANTOR LECTURES.

The Cantor Lectures on "The Constituents of Essential Oils" by LIONEL GUY RADCLIFFE, M.Sc.Tech., F.I.C., have been reprinted from the *Journal*, and the pamphlet (price 2*s.*) can be obtained on application to the Secretary, Royal Society of Arts, John Street, Adelphi, W.C. 2.

A full list ot the lectures which have been published separately and are still on sale can also be obtained on application.

PROCEEDINGS OF THE SOCIETY.

THIRD ORDINARY MEETING.

WEDNESDAY, NOVEMBER 22ND, 1922.

THE RT. HON. LORD NEWTON, IN THE CHAIR.

THE CHAIRMAN, in introducing the lecturer, whose name, he said, was well known to all who were interested in the question of smoke abatement, said what had always struck him about the matter was the astonishing apathy and want of interest which was shown in it by the public generally. He took, for instance

the press, which was supposed to be (erroneously very often) a correct expression of public opinion. He hardly ever saw anything in the press with regard to the particular subject of smoke abatement at all. He supposed it would be unbecoming on his part to make any suggestions to the press, as it might be looked upon as impertinence, but if they would give one-thousandth part of the space which they at present devoted to football to the question of smoke nuisance, Great Britain would be appreciably nearer to being a clean country than it was at the present moment. He hardly ever took up a paper without reading some alarming statement about the excessive dangers which this country was suffering from owing to the use of cocaine. He hardly knew what cocaine was. He had never employed it himself; none of his friends, so far as he was aware, took it, and he was not aware of any person, male or female, who was suffering from its influence. On the other hand, however, he knew millions of people who were suffering from the real nuisance of smoke and dirt, and whose lives were made uncomfortable, unhealthy and expensive in consequence. The causes of that grievance were plain enough. There were two. The first was the practice which prevailed in this country of using raw coal for all purposes without any moderation at all. From the point of view of cleanliness, the abundance of raw coal in this country had been little less than a calamity. That was the cause of the dirt from which we suffered. The second cause was the apathy which had always prevailed on the part of the Government with regard to the question. The task of arousing people had been left to private individuals, and it must also be admitted that some of the municipalities of big towns had done their best, under very discouraging circumstances, to grapple with the evil. In their efforts they had never met with the smallest assistance from London. The Local Government Board, whilst it was alive, had actually prided itself on the fact that it had never done anything whatsoever with regard to the matter, and had never taken any steps to enforce legislation on the Statute Book about it. Shortly before the war, a more intelligent Minister than usual was in charge of the Local Government Board, namely, Mr. Herbert Samuel, who appointed a Committee for the purpose of enquiring into the question. That Committee sat for a short time, and then its work was interrupted by the war. When the war came to an end the Committee was re-appointed by Dr. Addison, and he (Lord Newton) occupied the position of Chairman. That Committee sat for over two years and examined every sort of person. Very eminent men provided the Committee with interesting statistics with regard to health and waste of money and expenditure, and many other facts, but very few people took any interest whatsoever in the proceedings. The only real flutter of interest which that Committee ever succeeded in creating was when a lady of high rank, moving in fashionable circles, appeared and complained that her blouse had been discoloured in the operation of harvesting in the neighbourhood of Glasgow. When that lady's case was disposed of the Committee ceased to attract any attention whatsoever. It seemed to him that the Committee might just as well never have sat at all, because he observed that the London County Council, of all bodies, had the previous day passed a resolution in favour of enquiring into the very question—a question which his own Committee had been carefully investigating for two or three years, and which had issued a voluminous report. Evidently the London County Council was quite ignorant of the fact that a Government Committee had enquired into the matter. In view of that sort of apathy, and in view of the fact that Dr. Addison had treated them with more contempt than anybody else, it was not surprising that nothing had been done. Dr. Addison, who had asked the Committee to provide him with a report in connection with his Housing Scheme, had deliberately ignored it, and it was not until he (Lord Newton) had complained in Parliament that that particular report was brought to the notice of the various building authorities throughout the country. As he said, it was not very surprising, in view of that apathy and in view of the attitude taken by the press and, in fact, by nearly everybody, towards the question, that the Government had not been disposed to do anything, and he did not think anything would have been done unless a very important and influential deputation, including doctors, architects, scientific men, chemists, authorities on art and so forth, had waited upon Sir Alfred Mond and represented to him that, on the ground of economy alone, it was desirable that legislation should be introduced in Parliament and founded upon the Committee's report. The result was that a Bill had been introduced at the fag end of last session, that was to say, in the expiring moments of an expiring session of an expiring Parliament—and the Bill was nothing but a formal acknowledgment, so to speak, of the pledge. There was very little in the Bill that was of any value at all. It had been suggested to him by the Government that everything contentious should be put in by himself and his friends; in other words, the Government proposed to take the credit of introducing the Bill, and to leave him and his friends the task of putting in everything that people were likely to oppose. He did not think that that was a businesslike way of proceeding. He need hardly tell his hearers that private members and persons in his position were not able to get important amendments carried in Government measures. It was the duty of a Government to tackle the question itself, and that brought him to the conclusion

of his remarks. He thought the moment had come when everybody who was interested in the matter ought to unite and try to induce the present Government to consider the question again. The people had been told that the new Government was "a safety first Government." He took it that "safety first" meant not embarking upon any dangerous or contentious legislation. What more fertile field was offered than the question of smoke abatement? It was not a party question at all, and he was quite sure that if any reasonable measure was brought in by the Government it would receive the support of every intelligent person in the country, unless his own particular interests were involved, and that, of course, was a difficulty which had always to be contended with.

The following paper was read:—

THE ECONOMY OF SMOKE ABATEMENT.

By EX-BAILIE WILLIAM B. SMITH (Glasgow),

Member of the Departmental Committee on Smoke Abatement.

At various times many of our citizens have agitated for the removal of the smoke nuisance, but it is only within quite recent times that some serious effort has been made to improve matters. Formerly, those who caused the emission of smoke, whether manufacturers or householders, either maintained that it was impossible to prevent smoke or that, though it might be possible in theory, in practice it was so costly that it was not practicable to stop it. Manufacturers said that if they were interfered with by any regulations to prevent smoke they would have to close their works, or go to some place where the regulations were not enforced.

On December 8th, 1863, a public meeting of the manufacturers and furnace owners of Glasgow, was held for the purpose of receiving the report of the Committee appointed at a meeting held on the 17th September. The report referred to the highly extortionate and oppressive treatment under which the Glasgow manufacturers have suffered as compared with those elsewhere and to "the arbitary, expensive and altogether objectionable character of the Green Act," and it was resolved to obtain from the Police Board instructions to the Fiscal and the Smoke Committee to abandon entirely the Green Act and to work the General Act in a temperate and conciliatory manner such as is adopted in London and elsewhere.

Mr. Robertson urged the adoption of some plan by which cases of nuisance might be dealt with quickly and a fine of 5*s*. or £1 imposed.

Until quite recently, the great difficulty was to suggest some alternative to the smoke producing methods. Now we have methods that are not only practicable, but that actually are more economical and might be adopted on that ground alone, and it is chiefly on that view of the question that I address you to-day.

Immediately after Mr. Herbert Samuel was made President of the Local Government Board, he took up the subject and appointed a Departmental Committee:—

> "to consider the present state of the law with regard to the pollution of the air by smoke and other noxious vapours and its administration, and to advise what steps are desirable and practicable with a view to diminishing the evils still arising from such pollution."

They began to take evidence in May, 1914, and met at intervals until War broke out, when their meetings were stopped.

In January, 1920, Dr. Addison, then Minister of Health, reconstituted the Committee, which met at intervals till December, 1921, when they presented their final report. On 1st June, 1920, they issued an Interim Report on the subject of domestic smoke, with particular reference to the Government Housing Schemes.

I attended all the Meetings of the Committee, and the fact that impressed me most, was the amount of evidence to show that prevention of smoke was not only possible, but that it resulted in a saving of money, that generally absence of smoke meant greater economy, that wherever the atmosphere was being polluted, there was loss, both directly and indirectly.

To refer first to the subject of our Interim Report:—smoke produced by burning raw coal in grates and fireplaces of the domestic type in dwelling houses and business premises.

About that the Report says:—

> "The burning of raw coal is from the national point of view, a wasteful proceeding. Not only are the valuable by-products of tar, oils, ammonia, sulphur and cyanogen compounds lost, but, in addition, a large proportion of unconsumed fuel escapes in the form of soot, owing to inefficient appliances.

"Nearly 2½ million tons of soot escape into and pollute the atmosphere every year from domestic fireplaces alone, in the United Kingdom.

"It has been established that methods are available for warming rooms, cooking, and the provision of hot water, which avoid much of this waste, which produce little or no smoke, which are hygienic and economical, and which save labour.

"It appears to us that the great housing schemes which are now being undertaken with the aid of Government subsidy afford a unique opportunity of securing the adoption of these methods in the new houses.

"Raw coal burnt in open grates inevitably produces smoke which may almost be eliminated by the substitution of smokeless heating agents."

Mr. Rusten, of Leeds University, in his evidence to the Departmental Committee, said:—

"Sir W. Roberts-Austen and Professor Cohen, have each made a large number of determinations of the quantity of soot emitted from domestic fireplaces, and both are agreed in putting it roughly at 6 per cent. Experimental evidence, therefore, goes to show that one could not be very wide of the mark in stating that, as far as the householder is concerned, for every ton of coal he buys, one hundredweight goes up the chimney unconsumed."

Mr. Harris, Chief Chemist of the Glasgow Corporation, in 1908, during a series of experiments with domestic coal fires, found that over 5 per cent. of solid matter was carried up the chimney unconsumed, consisting of

Mineral matter ...	22.0	per cent.
Carbonaceous matter	41.1	,,
Oily hydrocarbons ...	36.0	,,

of which he said:—

"These impurities are most objectionable, as besides being conducive to the formation of that abomination—black fog —they retard its dispersion, because on a reduction of atmospheric temperature they are condensed and precipitated with the accompanying moisture, forming an oily envelope surrounding the globules of condensed water, which prevents evaporation to a very considerable extent."

Most of the fog in our cities and towns is caused by this solid matter thrown into the air from the domestic type chimney. Mr. Ruston said, that when coal is burned in a boiler furnace, the amount of solid matter carried up the chimney is only from 0.5 to 0.75 per cent., and that the soot from the domestic fire was much worse as it contained a high percentage of tar, sometimes as much as 40 per cent. It is principally the presence of this tar—or tarry oil—that makes smoke so injurious to health and property.

It was stated in evidence that even in industrial areas a large proportion of impurities in the air were from domestic type fireplaces; in Leeds quite 50 per cent., in Manchester, even more. In Glasgow, in winter time, I estimate that it may be up to 80 per cent., except when the wind is easterly and smoke is blown over us from industrial areas beyond our boundaries, where the local authorities take no action against manufacturers. In London it seems about the same as Glasgow, as similar amounts of deposit per acre are recorded in the instruments in use in both cities to measure the soot fall and the composition of the impure deposit is about the same.

Being convinced from the evidence given, that domestic smoke was so injurious, the Committee said:—

"We are satisfied that means which produce little or no smoke are available and practicable for cooking, heating water, and warming rooms."

And recommended—

"That the Central Housing Authority should decline to sanction any housing scheme submitted by a Local Authority or Public Utility Society, unless specific provision is made in the plans for the adoption of smokeless methods for supplying the required heat as suggested in the body of this Report. The only exception to this rule should be when the Central Authority are fully satisfied that the adoption of such methods is impracticable."

In their final Report, referring to this subject, they said:—

"In our Interim Report, we mentioned a number of economical methods which are available for warming rooms, cooking and the provision of hot water, which produce little or no smoke, which are hygienic and which save labour. We note with regret that the Ministry of Health have not required gas heating and other smokeless arrangements in the new houses

erected under the housing schemes. We desire in this connection to draw attention to our recommendation in the Interim Report that 'The Central Housing Authority should decline to sanction any housing scheme submitted by a Local Authority or Public Utility Society, unless specific provision is made in the plans for the adoption of smokeless methods.'"

About the cheapest schemes of all for detached houses seemed to be that which the Committee saw at the Austin Motor Co's. village at Northfield, near Birmingham. In each cottage is a small boiler, burning coke, which can warm the whole house by means of a radiator in each apartment and can supply the hot water required for every purpose. To do this only required about 5 tons of gas works coke per annum; the cooking and lighting were done by gas.

In addition to the saving of cost to the occupier, there was considerable saving in structural cost, as the installation of boiler, radiators, etc., was about £30 less per house, than if it had been fitted with the old fashioned coal-burning grates and the necessary fireplaces and chimneys. For houses built on the tenement system and for detached houses fairly close together, a hot water system supplied from a central boiler installation would be still more economical and labour saving for the occupier.

But a great majority of British people do not like this mode of heating, they want to see the fire itself, and prefer—perhaps rightly—radiant heat to convected heat from hot water radiators. So to meet their wishes and still avoid the smoke, waste and extravagance of the old fashioned fire, the Committee recommended the use of gas, about which they said:—

> "The principal advantages of the use of gas are its efficiency (better utilisation of the heat), cleanliness, and the ease with which it can be turned off when not required (intermittent use). These advantages often more than compensate for the higher price of gas when measured by thermal units."

Therefore, I recommend for the consideration of all who have to do with the erection of new houses, where gas is available at reasonable cost, that in each house there should be installed one of the new type boilers burning coke, capable of being used as a closed up or open fire at will, to warm the living room and to supply the hot water required for all purposes; because the cheapest method of heating water is by a coke-fired boiler. The flue from this boiler should not be of so large a diameter as the flues and chimneys put in for ordinary coal grates, as the better draught makes this unnecessary and a flue not any wider than actually required is less liable to down draughts.

A wash boiler should be fitted in the scullery, set just through the wall and back to back with the coke boiler, supplied with hot water from this boiler, and with a gas burner under it to raise the hot water up to boiling point when required; the flue from it going up into the flue from the boiler. In the scullery also there should be a gas cooker, provided with a canopy and pipe into the boiler flue to carry off all products of combustion both from the oven and boiling rings.

In each bedroom there should be a gas fire, with a flue of long narrow section in the special bricks forming part of the wall. These bricks might also contain a second ventilating flue. This would save money in construction, being cheaper than the deeper fireplaces and wider flue and chimney stack and cans. The lighting would be done by gas.

About Electricity, the Committee said:—

> "Electricity has also been urged as an efficient method for cooking and for warming rooms, but not, owing to its present cost, for heating water. From a hygienic and labour saving point of view, electric cooking and heating has much to recommend it, but we hesitate to advise its adoption on the evidence before us, in view of the high price at present charged for electricity in many localities."

Where it has been decided to instal electricity for lighting, and a reasonable price can be charged for current, the house should be equipped with the coke fired boiler in the living room and wash boiler in scullery, as in the gas house, but the cooker would be electric, and in each bed room would be an electric radiator. It would probably be cheaper to do cooking and the heating of the bedrooms by electricity, where heat is usually only required occasionally, and for short periods, than to instal a coal cooking range and grates, with the extra building in, and chimneys. Some electricity undertakings made this practicable.

In Glasgow, for 13 years current for domestic cooking, heating, etc., has been sold at a special rate; to-day current for lighting is charged at 4½d. per unit for the maximum demand of 800 hours per year for the lights installed, which is the average consumption of current used in a house for lighting, and whenever electricity is used in a house for cooking, heating, ironing, vacuum cleaning or other domestic purposes, the charge for current over this 800 hours is 1d. per unit. This system requires only one meter and one set of wires for both lighting and power, so that a vacuum cleaner, iron, kettle, etc., can be connected to any plug or lamp socket on the lighting wire in any room, and current equal to one and one-third horse power for one hour is supplied in the house for one penny, and that rate pays the department, as the most of this current is taken at a time off the peak load of maximum demand, and the rate charged for lighting has paid the proportion necessary for Interest, Sinking Fund, Depreciation, etc.

For the first time in our history, the plans and details of construction of dwelling houses to be erected in Britain were under the jurisdiction of one central authority, the Ministry of Health, who might be supposed to look at everything principally from a health point of view, and the financial aspect of all the schemes came under the control of the Treasury, because part of the cost was to come out of Imperial Funds.

Under such control one would have expected that methods which were more healthy and would cost less to provide, would be recommended or even insisted on.

Has any action been taken by the Ministry of Health to carry out this recommendation? I cannot find any. The Scottish Board of Health tell me they got the report, but have received no instructions from the Ministry to act on it.

I cannot find that any action was taken in England by the Ministry of Health to enforce—or even suggest—any of these methods, or in fact any smokeless method whatever, in the plans submitted to them for approval, but, as far as I can learn, without comment, they seem to have passed and approved of plans showing the old fashioned smoky fireplaces, although all the smokeless methods actually cost less money in construction. In recommending them to take action now on all new houses, we were only anticipating the adoption of smokeless methods which the people themselves are beginning to insist on. Housewives are getting tired of the old conditions and are anxious to get rid of the old fashioned cooking range or kitchener, and all the dirt and labour it entails, and in its place desire to get a cooker where the heat can be got at any moment of the day or night simply by turning a tap, just as they now get water in the house by turning on a cran instead of the old and troublesome method of drawing it out of a well.

What applies to the cooker, applies to other fireplaces in the house: whether in in the living room, drawing room or bedroom, the gas fire has every advantage over the coal fire. It eliminates the necessity for carrying in coal, building the fire, lighting it perhaps long before it is required, keeping it lit during intervals when it is not necessary and leaving it in long after it is finished with, removing the ashes and cleaning the grate daily. Whereas a gas fire, properly fitted in, is equally healthy, promotes adequate ventilation, can be lit at any moment, and reaches full temperature in a few minutes, and can be adjusted to give the temperature desired. In the case of illness, it is invaluable, it can be kept on for days together, and avoids the disturbance of the patient by replenishing and cleaning the coal fire. Yet some people tell us they like the old fashioned coal fire. If, when it is being lit or charged, they would go outside and look at their chimney, they might think less of it and more of the gas fire.

As the Government Departments concerned seem reluctant to take action to improve matters, we must try to offer smokeless methods that will appeal to the householders by their convenience and economy.

If we can put on the market a smokeless fuel that is better than raw coal, we can immediately prevent smoke from the fireplaces as they are at present, and it was while working in this direction that I came on a solution — not only of the domestic smoke pollution—but also that from industrial chimneys. Ever since I have worked at the problem of smoke abatement, I have been impressed with the necessity for a smokeless fuel, that will kindle and burn in an open grate as easily as coal. In 1910, addressing a meeting of gas managers, I predicted a greatly increased demand

for gas for domestic use, and said that they would have to find a process of making gas that would produce, at the same time, a coke that could be used as a smokeless fuel, instead of coal, under all ordinary conditions; and from that time I enquired into every process I could hear of that might fulfil this condition. After a time, I found one that seemed to meet both demands, for a good smokeless fuel and cheap gas, and that was the Maclaurin process of low temperature carbonization.

With regard to some of the manufacturing processes where large volumes of smoke are being produced, the evidence given to our Committee was in many cases conflicting, some manufacturers maintaining that it was quite impossible for them to carry on their various processes without emitting smoke, and others stating and even proving that smokeless methods were not only possible, but better in every way. One instance of this was that of firing pottery. In 1914 the manager of one very important pottery informed the Committee that it was quite impossible to fire and glaze their productions without excessive smoke; another witness, following him, assured us that he had so altered and improved his methods that he quite prevented smoke and reduced the cost of firing. When the Committee visited Stoke-on-Trent, one witness, who is an experienced potter, and a recognised authority in the district, told us that it was not possible to fire certain kinds of china without smoke, that it could only be done by means of raw coal, in the old fashioned way; but later witnesses assured us that not only could it be done, but it was being done; and when visiting various potteries we saw several where firing by gas was being successfully carried out, and were told that the use of gas saved about 70 per cent. of the cost of fuel. I have visited the district on two occasions since then, and have seen at work a gas firing system invented by Mr. J. H. Marlow, of Messrs. Minton, Hollins & Co., Stoke-on-Trent, where, with producer gas made from 21 tons of coke, they got the same amount of work done that under the old system would have cost them 90 tons of coal. Not only is there the saving of 69 tons of fuel, but the price of the coke to-day is only 20*s*. per ton, while the coal is 35*s*., and there is a saving in the cost of labour of fully 33⅓ per cent. Under such conditions, one may reasonably expect that the old methods will very soon give place to the new, although I am quite aware that to make the change means a considerable outlay of capital, and in many cases a larger area of ground is necessary. Pottery is only one instance where gas might be substituted for solid fuel. In many metallurgical processes gas is a more ideal fuel, more easily applied, and the temperature desired much more under control. But for this purpose, an extremely cheap and plentiful supply of industrial gas should be available, and the smokeless fuel process supplies that too. The prospects of great increase in the production of gas and its use for many purposes, even for steam raising, are greater now than ever before, although the cost of gas for steam raising compared with coal is the severest comparison that can be made.

When the Gas Act of 1920 made the therm a legal standard of measurement, it enabled users simply and easily to compare the cost of the heating value of gas with that of other fuels.

The position has now changed, and to-day the Gas Industry is free to consider new schemes for the production of gas, and new outlets for the consumption of it, which a few years ago were outside of the range of practical policy.

Let me try and show how near we are to an era when smoke will be a thing of the past and that without compulsion being required.

Taking the therms in an average ton of coal as 267, we can readily calculate the costs of one therm of heat actually utilised, assuming certain reasonable efficiencies and probable costs for gas and coal under different conditions:—

	Efficiency taken for Coal.	Efficiency taken for Gas.	Cost per therm utilised.			
			With Coal at 40/-	With Gas at 9d. per therm.	With Coal at 20/-	With Gas at 3d. per therm.
Cooking	10 %	50 %	18*d*.	18*d*.	9*d*.	6*d*.
Heating	25 %	60 %	7.2*d*.	15*d*.	3.6*d*.	5*d*.
Steam raising	70 %	70 %	2.57*d*.	12.8*d*.	1.28*d*.	4.3*d*.
High temp. operations ..	15 %	70 %	12*d*.	12.8*d*.	6*d*.	4.3*d*.

From the foregoing table it is evident that with gas at 9*d.* and coal at 40*s.*, gas will be as cheap as coal for cooking operations. That for gas fires, gas has to rely for its economy, upon its convenience and indirect saving of labour, and use only when actually required. That gas is hopeless for steam raising, and hot water heating in bulk, but for high temperature operations it can be utilised. With coal at 20*s.* and gas at 3*d.* per therm, cooking and high temperature operations would be cheaper with gas. Domestic heating for long periods would appear to be rather dearer, but in practice it would actually be cheaper. Steam raising would be out of consideration for large installations with efficient management and constant load and good boilers. Before gas could hope to displace coal for steam raising the cost would require to come considerably under 3*d.* per therm.

The balance of economy in favour of gas is so slight at the present time that no great impetus is given to its more general adoption, although, no doubt, it is steadily but slowly gaining ground; but if the cost of the gaseous therm can be reduced to one-third or one quarter of its present cost, the balance will then swing so strongly in favour of gas as to make its development extremely rapid. This is foreshadowed in the Fuel Research Board's Report on "The Therm," just issued, paragraph 39, 40 and 41—

> "For some industrial purposes water gas is an ideal gaseous fuel; for other purposes a gas rich in methane or other hydrocarbons is best. The proposed system of charging will give the producers freedom either to modify the character of the general supply to meet the special industrial needs of the district, or to deal with the situation by setting up a dual supply system. While it is admitted that any general duplication of mains and supply is quite out of the question at present, yet in the type of cases referred to in paragraph 39, it might be quite feasible to have special pipes delivering a different supply over a short radius from the gas works. We anticipate that the adoption by the gas undertakings of the system of charging only for thermal units of energy actually delivered to the consumer will greatly stimulate the industrial use of gas, and as any great extension of consumption must inevitably involve an increase in the capacity of the distributing mains and plant, the more general adoption of a dual supply system may not be so far as many of us have supposed."

In considering the efficiency of coal versus gas for steam raising, for simplicity we can assume that one therm theoretically will evaporate 100 lbs. of water from and at 212°F. Therefore, 10 therms will evaporate 1,000 lbs. theoretically (966 lbs. to be exact). In ordinary practice, however, the efficiency varies from about 70 per cent. to 50 per cent. of the theoretical, and as is natural, the lower efficiencies are obtained from the poorer fuels.

If we take the cost of coals of different qualities, and the labour of firing and removing ashes to be as under we get:—

	Average Coal.	*Poor Coal.*	*Gum*
Therms per ton ..	268	235	179
Cost per ton at Gas Works	20/-	14/4	6/-
Cost of Labour per ton..	3/-	3/-	5/-
	23/-	17/4	11/-
Probable Efficiency	70%	60%	50%
Cost of 1,000 lbs. of Steam	*d.* $\frac{276\times10}{268\times.7}$	*d.* $\frac{208\times10}{235\times.6}$	*d.* $\frac{132\times10}{179\times.5}$
=	14.7*d.*	14.7*d.*	14.7*d.*

The cost of steam under these conditions, which are fairly typical of costs and efficiencies to-day, seems to be within a fraction of 15 pence per 1,000 lbs. from and at 212°F. The cost of steam is not likely to vary much from this, with present prices, unless when the boilers are under scientific control. The cost of steam raising with coal firing and evolution of smoke is, therefore, likely to be 15 pence per 1,000 lbs.

It is possible to produce steam with gas firing for the same cost. We can safely assume an efficiency of 70 per cent. for gas firing, as this would be more easily maintained under ordinary works conditions, than the 70, 60 and 50 per cent. used for the three typical fuels. 88 to 92 per cent. efficiencies are possible with specially constructed gas fired boilers, such as the Bonecourt boilers.

At 70 per cent. efficiency, to obtain steam at the same cost as from coal, gas would require to be produced at the gas works at practically one penny per therm, thus:—

$$\frac{10 \text{ therms} \times 100}{70} = 14.3 \text{ therms.}$$

That is, at 70 per cent. efficiency it will take 14.3 therms in place of 10 therms to produce 1,000 lbs. of steam.

$$\frac{14.7 \text{ pence}}{14.3 \text{ therms.}} = 1.03d. \text{ per therm.}$$

That is, with gas at 1.03*d.* per therm, 1,000 lbs. of steam will cost 14.7*d.* It appears to me quite possible to produce gas at this price. I give here the yields obtained in a test made by Glasgow Gas Department, also values of the different products obtained per ton of an average coal, placing a value of one penny per therm upon the gas produced, and using for the other products, the values placed upon them by the Fuel Research Board as far as these apply. You will see that the expenditure can be met by the Revenue, and a reasonable interest remain over on the capital cost of the plant.

Calorific value of coal 12,300 B.Th.Us. per 1 lb. is—275 Therms per 1 ton.

Moisture	5%
Volatile Matter ..	30%
Coal used in Test ..	83 tons.

Products with their value per ton of coal carbonised—

Oil 15.6 gallons at 5*d.* ..	78.0*d.*
Ammonia 17 lbs. at ¾*d.* ..	12.75*d.*
Gas 27,731 cu. ft. of 247 B.Th.U.s	68.33*d.*
=68.4 therms at 1*d.*	
Total coke—11 cwts. at 1*s.* 5*d.*	187
	346.08*d.*

or 28*s.* 10*d.*

The capital cost of a battery of 5 units of Maclaurin Producers, capable of carbonising 100 tons of coal per day, and making 2¾ millions cu. ft. of 247 B.Th.U. gas, is estimated at to-day's prices at about £20,000. Assuming the same average coal is used, for carbonising, as was used for steam raising, the price must be taken as the same, viz., 20*s.* per ton. The expenditure then is:—

	Per ton. *s.*	*d.*
Coal	20	0
General charges and stores are estimated at	2	0
Steam and Power		6
Labour	1	6
Foreman and supervision		6
15% depreciation and repairs on £20,000 with a throughout of 30,000 tons per annum—13*s.* 4*d.* per ton	2	0
Available for interest on capital, etc.	2	4
	28	10

This is practically 17.5% on the capital.

The cost of distributing gas to points within 1,000 yards of a depot, in quantities of 150,000 cu. ft. per hour, allowing 20% for interest, depreciation and maintenance of mains, would amount to about one-tenth of a penny per therm.

In paragraph 48 of the report of the Board of Trade on "Gas Standards," the Fuel Research Board say—

"The sheet anchor of the gas industry in the future must necessarily be its possession of the cheapest known means of distributing potential heat energy in a convenient form."

To distribute the 275 therms in a ton of coal as gas would, therefore, cost practically 2*s.* 3*d.*

It is hardly possible to distribute coal at that figure. To places within 2,000 yards, that is a trifle over one mile, the cost of distributing 275 therms as gas would be at 0.2d. per therm, about 4*s.* 6*d.* Evidently then therms can be distributed as gas about as cheaply as therms in coal can be distributed.

The convenience to the small manufacturer of getting his energy delivered into his work in pipes as against getting it in by carts, and removing ashes, etc., should make a strong appeal. Gas undertakings, by virtue of their being large purchasers of coal would be able to obtain their coal at lower prices, and this would be in favour of the distribution of gas as compared with coal. I am quite ready to admit that apart from the convenience to the smaller steam users, the margin of cost between gas and coal is too narrow to anticipate rapid developments in the supply of gas for steam raising. It is to those industries in which gas is used for power, or for high temperature operations that gas would at first make the strongest appeal.

To consider power first, if we take the cost of one ton of coal delivered to a central depot, at £1, we must add for depot charges and cartage somewhere round about 5*s.* per ton, to arrive at the cost of coal delivered

to the industrial user who has no railway siding.

The cost of 1 h.p. hour will then be to him :

	s.	d.
Coal delivered, say 25s.	25	0
Labour, including removal of ashes	4	0
	29	0

Steam raised at 70% efficiency—18,760 lbs.

Seventy per cent. efficiency leaves little margin for standby losses of small manufacturer.

Cost of 1,000 lbs. of steam $\frac{29 \times 14}{18,760} =$ 1s. $6\frac{1}{2}d.$

If we assume 25 lbs. of steam per h.p. hour we get 40 h.p. hours for $18\frac{1}{2}d.$ =2.2 h.p. hours for 1*d.*

With electricity distributed at $\frac{3}{4}d.$ per unit, this would give 1.8 h.p. hours for 1*d.*

With gas distributed up to 2,000 yds., we would get for 9 h.p. hours for 1.2 pence =7.5 h.p. hours for 1*d.*

Evidently then gas can be produced and distributed for the production of power by means of gas engines much more cheaply than an equal quantity of power could be obtained from raw coal or electricity.

A supply of gas laid on to industrial concerns now using coal for high temperature operations would also lead to the abolition of smoke and to national economy.

Figures have already been placed before the Royal Society of Arts, in a paper read by H. M. Thornton, 16th April, 1920, showing that considerable savings could be made over coal in many high temperature operations by use of gas fired furnaces using town's gas at 3*s.* 9*d.* per 1,000 cu. ft. If these savings be possible when the gas supplied was costing from 6*d.* to 10*d.* per therm, then with an industrial gas which can be distributed at a fifth of this cost, the advantages of gas over coal would be so great as entirely to displace coal from most high temperature operations.

Calculating from figures given in this paper, it is seen that in some cases eight therms are required to be used up when coal is the heating agent for one therm when gas is used ; that to produce 65 cwts. of forgings, 9 tons of raw coal were used and all their impurities thrown into the atmosphere instead of gas from only 5 tons of coal, leaving all the coke and other products from those 5 tons of coal to use for other purposes.

Gas undertakings may now add a new department to their works that may, in time, become as important and quite as remunerative as their present trade, namely, that of supplying gas for heat and power to industries and making smokeless fuel for all purposes. They will be able to deliver gas for power and heat to a manufacturer at less cost than he could obtain it from producers in his own work. He ought to be able to buy his gas from a central source, just as he gets his electricity more cheaply than he can generate it himself. Gas undertakings can do this by making an industrial gas and delivering it in special mains in industrial areas and, at the same time, producing smokeless fuel for which there is a great demand and many new by-products. Mr. Milne Watson, when giving evidence to the Departmental Committee on Electrical Supply, suggested that gas undertakings might carbonize the coal and deliver the gas to the electricity undertaking for their source of power, and with this I heartily agree.

DOMESTIC SUPPLY.

We have seen that gas can be carried to a point outside the consumer's house at an inclusive cost of 1.2d. per therm ; we have now to find what it will cost to carry it inside the house. We may do this on the assumption that it means installing a separate meter, larger than the present one, and pipes of larger bore led to the different fireplaces and cooking stoves. If we take a household consuming not more than four tons of coal per annum, as a fair average, we can arrive at a fairly close estimate of the quantity of gas such a house would consume per annum, and also an approximate idea of the plumber work involved. Four tons of coal is equal to 1,080 therms. If the coal were all burned in open fires, about 30 per cent. of the heat only would be left in the room, whereas, with gas fires, 60 per cent. would be utilised. That is, half the therms in gaseous form will be as satisfactory as double the therms in coal, and half 1,080 is 540.

The efficiency of coal in the kitchen range is put as low as seven per cent. ; the efficiency of gas for cooking is certainly well above this, so that, in practice, fewer therms in gas than half will do the household requirements.

The cost of a ton of coal delivered to the average household is from 32*s.* to 38*s.*, when coal is purchasable by the gasworks round about 20*s.* Taking the cost of coal at 35*s.* per ton, we get an annual coal bill of £7 for this typical family.

If we assume the capital cost of new pipes to be £10 per house, and allow 25 per cent. per annum for this, it means an annual cost for interest, etc., of £2 10*s.*

If 540 therms were delivered to this household at 3*d.* per therm, it would only cost them £6 15*s.* per annum. Deducting £2 10*s.* for the piping leaves £4 5*s.* for 540 therms of gas at the point of delivery, or practically 1.9*d.* per therm.

We have seen the possibility of supplying gas at 1.2*d.* per therm, so that, if the will exists, gas can be supplied to replace coal at prices which all classes can afford.

It might be argued that the cost of 1.2*d.* per therm for gas was based on getting 1*s.* 5*d.* per cwt. for the smokeless fuel, whereas, if the use of gas became general, the demand for smokeless fuel would be so limited that the price would not be higher than coal per ton. The cost of gas per therm at the depot, with smokeless fuel at 1*s.* per cwt., would only be raised to 1.52*d.*, and adding .2*d.* for distributing, we get 1.72*d.* at the consumer's premises. With gas at 3*d.* per therm, a gas fire in continuous use would be cheaper than a coal fire, with coal at 35*s.* per ton. It would also be so cheap that it could be used for hot water heating, and for this purpose would be cheaper than coal, because of the much greater efficiency obtained.

The objection to two sets of mains is, at first sight, formidable, but if gas has really to displace coal on a large scale, new mains are imperative in any case, and in most houses new pipes and new meters will also be required.

Eventually, the cheaper gas would be used for lighting also, and the present inadequate mains could then be scrapped or used as feeders.

For larger houses, the relation between the capital charges for plumber work and the therms in the gas supplied will be somewhat in the same proportion as for the smaller house.

We have seen that it is possible to supply gas to the domestic consumer sufficiently cheaply to displace coal.

The process, however, will set free for the market large quantities of a smokeless fuel for which a market would require to be found at a price at the works between 1*s.* and 1*s.* 5*d.* per cwt., according to the price obtained for the gas.

With coal at 1*s.* per cwt., smokeless fuel for domestic purposes would give practically an equivalent value at 1*s.* 5*d.* per cwt., so there would be no loss involved to the householder in its purchase.

With the more extensive use of gas, however, the domestic outlet for smokeless fuel would diminish.

An outlet for the fuel made in the central depots would then have to be found in industry.

We have already seen that gas can be supplied to industries within a certain radius of a gas works sufficiently cheaply to allow it to displace coal.

Therefore, a smokeless fuel must find its outlet in those industries beyond this radius, or for those uses in which pipe lines are impracticable, such as, road and railway locomotives, for use on the streets in tar boilers, etc., for river steamers; for most of these uses the fuel has been found eminently suitable. Larger outlets would be found in the industries outside the central area.

The fuel has been used successfully for producers, for steam raising, and for blast furnaces, and, therefore, has a sufficiently large market to absorb all that is likely to be produced for many years to come.

The utilisation of this fuel as a domestic and industrial fuel in those areas outside of the spheres where gas works are established, will reduce the smoke produced in the outlying districts, and, therefore, benefit the whole country.

A short description of the Maclaurin process, which seems capable of doing this, may interest you. It is not elaborate, but simple.

I shall, therefore, describe the plant and the method of working it as fully as the time at my disposal will permit.

In outward appearance, it somewhat resembles a miniature blast furnace, but it is built square. Its overall height is about 45ft., and its internal diameter at the widest portion is 8ft. This is at a point a little below where the air enters.

The air blast is distributed through a large number of narrow ports in the opposite side walls, and also by similar ports in a dividing wall, which is carried across the plant at the same level, for the purpose of

securing a uniform distribution of the air blast.

Above the air ports the plant gradually narrows till about 10ft. above it has narrowed to about 3ft. 6in. diameter. At this point the brickwork stops, and supports a cylindrical tank 8ft. in diameter and about 10ft. high. The bottom of this tank is projected upwards towards the centre, so as to provide a well for oil and water to collect in. An open internal cylinder dips into this well, leaving a space of about 2 inches all round between the two cylinders for the passage of the gas. Above this outer cylinder, which is termed the condenser, is placed the charging bell and coal hopper. Below the air blast lies the cooling zone, through which steam is passed. This steam enters at the discharging doors cooling the coke or residue. It also becomes highly heated and partly decomposed into water gas, which passes up mixed with the producer gas formed at the combustion zone.

The discharging doors are about 6ft. from the ground level, so that a tub can be run below to take the discharge, or a conveyor can be operated.

The plant when working contains about 30 tons of fuel. Working is continuous. Each hour from 18cwts. to 1 ton of coal is charged above and 10 to 12 cwts. of coke is taken out below, or if running for complete gasification the quantity of ash contained in the quantity of fuel put in, is withdrawn hourly.

The only adjustment made in the plant, if changing over from complete gasification to the manufacture of smokeless fuel or blast furnace coke, consists in the regulation of the air inlet and gas outlet valves.

The control of these valves enables the operator to run the plant so as to discharge an ashy residue, or an amorphous black fuel suitable for domestic purposes, provided the coal used has been suitable.

The principle upon which the plant works is as follows:—

The hot gases passing upwards from the combustion zone, coke the fuel coming down very slowly, through the ammonia-making zone. This term is applied to that portion of the furnace which is working at temperatures between 800° and 500°C, because herein part of the nitrogen of the coal is converted into ammonia. Each particle of coal is several hours in passing through this zone, and during this time is enveloped in an atmosphere containing both steam and hydrogen. This is why the ammonia yields are rather greater than in other low temperature processes.

Passing from this zone, the gases pass upward through the distilling zone, carrying with them the oil vapours given off from the distilling coal.

The bulk of the distillation is taking place at temperatures between 500°C and 300°C. The vapours given off at 500°C are rapidly swept upwards into cooler regions and, therefore, suffer a minimum of decomposition. Proceeding upwards, the gas, saturated with oil vapours, passes the collar of the plant and enters the condensing chamber. Here the gas spreads out into the cooler fuel coming down, and as the velocity decreases, rapid condensation takes place. The oils which condense outside the central 3′ 6″ core, naturally trickle down to the bottom of the condenser where they are caught in the well. The inner cylinder seals off the gas from travelling straight to the tubular outlet and forces it to traverse the incoming fuel, heating it up and partly stripping it of its water content. This trapping prevents the oil from concentrating in the cold fuel to such an extent as would cause it to trickle down into the hot fuel below. The high velocity of the gases at the constriction also prevents the oil trickling down. If the oil did so, the fuel would inevitably bind up into a solid mass.

The level of the oil and water trapped in the well rises until it reaches the level of the 12-inch main leaving the plant, when it flows along till it reaches the collecting tanks. The gas leaves the plant at a temperature of from 60°C. to 80°C., in place of about 700°C., as it does in ordinary producer practice.

The heat losses in the process are, therefore, very small, being confined to the heat carried away by the gases, the radiation losses from the walls of the plant, and the heat in the fuel discharged. The heat required is supplied by the combustion of a small quantity of the carbon in the coke. The carbon monoxide formed, however, is available afterwards in the gas.

This process has demonstrated that it is not necessary to leave a high percentage of volatile matter in coke to make it burn easily in an open grate. If the temperature of carbonization can be kept below a certain point, the carbon in the coke will be in the

amorphous form and easily combustible; but if the temperature gets above that point, the coke will get into the graphitic form; not easily burned in an open grate, but most suitable for blast furnace use.

Blast Furnace Coke and Smokeless Fuel.

The yield of blast furnace coke is rather less per ton of coal carbonised than in coke ovens, but, on the other hand, more power gas is available for use about the works or for sale.

The coke is formed under conditions somewhat similar to those which existed in the old beehive ovens, and is, therefore, likely to meet with favour when put upon the market.

The yield of smokeless fuel is rather less than from other low temperature processes, but the quality is better. The Maclaurin smokeless fuel is always uniformly coked to the centre; has no tarry portions, and is harder than the original coal, and, therefore, stands transport better than any smokeless fuel hitherto produced.

By screening the coke can be separated into large coke, smithy char and breeze.

The large coke is generally freer from ash than the other portions. This is shown in the following table giving the ash in the coke from three different types of coal.

	Percentage of ash.		
	1	2	3
Original Coal	7.85	6.29	8.68
Large Coke	8.83	6.48	8.40
Smithy Char	18.53	20.00	27.50
Peas	7.40	16.76	12.44
Dust	36.30	32.64	33.14

The stoney matter in the coal has, in each case, concentrated in the smithy char and the finer ash in the dust.

The large coke can be further cleaned by hand picking.

By a separation with water, the smithy char and peas can be brought down to about the same percentage of ash as the large coke. The volatile matter in the coke varies between 3% and 5%. The percentage of sulphur is about ⅔rds of the percentage in the coal.

I have been telling you of matters that are for the producer and user, now I want to show that they will be economical to the community in general.

Sir Frank Baines, Director of Works to His Majesty's Office of Works, in his evidence to the Committee, said that more than half the cost of the upkeep of public buildings in London was caused by the impurities in the atmosphere, and with him members of the Committee visited several buildings, including the Houses of Parliament and Buckingham Palace, and saw for themselves the enormous amount of deterioration going on. We also had evidence of the loss both to horticulture and agriculture in many districts, but above all there is the economy of life that should outweigh every other consideration. Many authorities have told us that a smoky atmosphere is bad for health—some have asserted the contrary, that it is a good disinfectant.

To illustrate the effect on health, I will take one of the worst examples I have experienced. This was a most extreme case, but the same thing goes on in a lesser degree every winter, in every town in Great Britain, but not in some other countries.

In Glasgow, during the winter of 1909, we had a series of exceptionally bad fogs; we have had nothing like them since, and I hope we never shall. It is usually very difficult to get a true standard of comparison in such matters, but I claim that I have it here. The Registrar-General, in his returns, forms a group of eight principal towns in Scotland; they are Glasgow, Edinburgh, Dundee, Aberdeen, Paisley, Leith, Greenock, and Perth. The population of Glasgow at that time was estimated by the Registrar-General at 872,021, and that of the other seven towns combined at 993,550. In all but one of these towns the conditions are practically alike; they are planned and built in the same style; they have about the same population of crowd and even slum areas; they have good water supplies, similar systems of sanitation, the same forms of control and inspection; the methods of heating and cooking are similar, and the general habits of their inhabitants are very much alike. Even the working conditions are comparable, as most of the industries in Glasgow are also carried on in one or more of the other seven towns.

But their geographical positions make it improbable that they all should have quite the same conditions of atmosphere at the same time. A glance at the map will show this—three are on the west, two on the east, and three north-easterly; five are on the coast, and three are inland. A drift of air from the east will carry smoke over some while it carries it away from

others; from the west it will pollute some and clean others. I have made no comparisons with rural or semi-rural areas, because many of their conditions vary from the large towns.

I remember reading what the late Dr. Russell, Medical Officer of Health for Glasgow, once said: "That during winter every city was in danger of a catastrophe if certain weather conditions occurred—a combination of keen frost, fog and a still air for days together." Having experienced that condition, I got the Registrar-General's returns as soon as published and studied them; I compared them with the atmospheric condition in Glasgow as I had noted it day by day, checking it with the meteorological records, and I submit them for your consideration.

During the summer of 1909 in Glasgow we reached the lowest death rate recorded up till that time, about 11 per 1,000. It rose a little as the winter came on, for the five weeks ending October 30th, the weekly average number of deaths from all causes was 223, equal to 13.4 per 1,000 per annum; and for the other seven towns the number was 233, equal to a rate of 12.2 per 1,000. Table I. shows what happened then.

From November 15th to 19th we had one of the worst fogs I remember, and for the week ending November 20th the number of deaths was 416—equal to 24.9 per 1,000—while for the other seven towns it was 15.3. For the following week, ending November 27th, Glasgow had 547 deaths—equal to 32.7 per 1,000—while the other seven towns were 16.7 per 1,000. During the week ending December 4th, the Glasgow death rate dropped to 27.3 per 1,000, the rate for the other seven towns rising to 17.8; but during the following week, on December 6th, 7th and 8th, Glasgow had another fog, and for this week, ending December 11th, the number of deaths in Glasgow rose to 529—equal to 31.7 per 1,000—while in the other seven towns it fell to 16.7. From then it began to decline in Glasgow, but increased in the other seven towns. The effect is even more striking if put in the form of Diagram 1.

The next point was to see what class of diseases had caused this abnormal increase of deaths, and it was found that those affecting the respiratory organs, called bronchial diseases, including bronchitis, pneumonia and pleurisy, were accountable for most of it. Table II. gives the deaths

TABLE I.

DEATHS FROM ALL CAUSES.

1909	Glasgow		7 Other Towns		Mean Glasgow Tempr	Weather Conditions in Glasgow	Mean Temp. in 7 Other Towns
	Number	Rate	Number	Rate			
October Weekly Average	223	13.4	233	12.2	49.2	Clear to dull	48.4
Week Ending							
6th Nov.	304	18.2	243	12.7	45.0	3 days Fog	44.3
13th „	300	18.0	266	13.9	44.0	Dull Slight Fog	41.7
20th „	416	24.9	292	15.3	30.7	5 Days Dense Fog	30.0
27th „	547	32.7	319	16.7	40.3	Hazy	37.9
4th Dec.	457	27.3	340	17.8	42.3	Hazy or Wet	38.1
11th „	529	31.7	322	16.7	37.0	4 Days Fog	34.7
18th „	384	23.0	316	16.5	38.5	Slight Haze	38.4
25th „	359	21.5	338	17.8	31.9	Slight Fog & Clear	32.4
1st Jan.	347	20.8	328	17.2	43.1	Wet or Clear 1 Day Fog	41.5

On October 30th and 31st we had a fog, and for that week, ending November 6th, the number of deaths was 304—equal to 18.2 per 1,000—while the rate for the other seven towns was only 12.7. The following week, ending November 13th, the Glasgow rate remained at 18 per 1,000, the other seven towns rising to 13.9.

from this group, and Diagram II. shows with startling clearness that it was caused by the diseases of the organs principally liable to injury by impure air. No doubt cold caused an increase in deaths from these causes, but that applied even more to the other seven towns where the temperature was slightly lower than in Glasgow, but there was

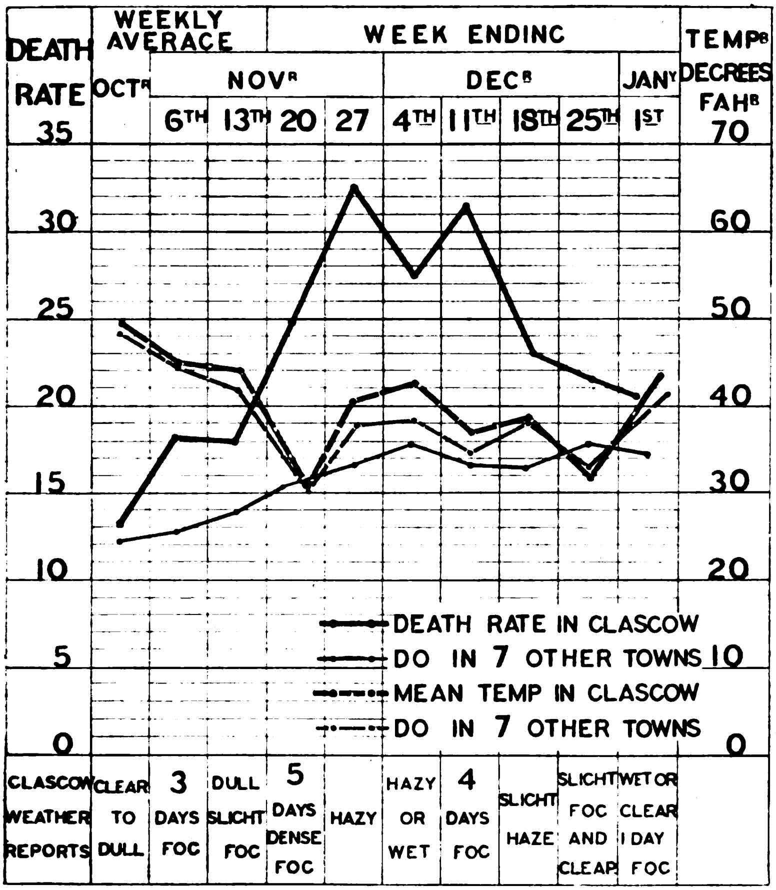

DIAGRAM I.

TABLE II.

DEATHS FROM RESPIRATORY DISEASES.

1909	Glasgow		7 Other Towns		Mean Glasgow Tempr	Weather Conditions in Glasgow	Mean Temp. in 7 Other Towns
	Number	Rate	Number	Rate			
October Weekly Average	35	2.1	31	1.6	49.2	Clear to Dull	48.4
Week ending 6th Nov.	61	3.6	44	2.3	45.0	3 Days Fog	44.3
13th ,,	75	4.5	39	2.	44.0	Dull Slight Fog	41.7
20th ,,	138	8.3	55	2.9	30.7	5 Days Dense Fog	30.0
27th ,,	233	13.9	63	3.3	40.3	Hazy	37.9
4th Dec.	171	10.2	93	4.8	42.3	Hazy or Wet	38.1
11th ,,	198	11.8	76	4.0	37.0	4 Days Fog	34.7
18th ,,	137	8.2	78	4.0	38.5	Slight Haze	38.4
25th ,,	95	5.7	76	4.0	31.9	Slight Fog & Clear	32.4
1st Jan.	93	5.6	88	4.6	43.1	Wet or Clear 1 Day Fog	41.5

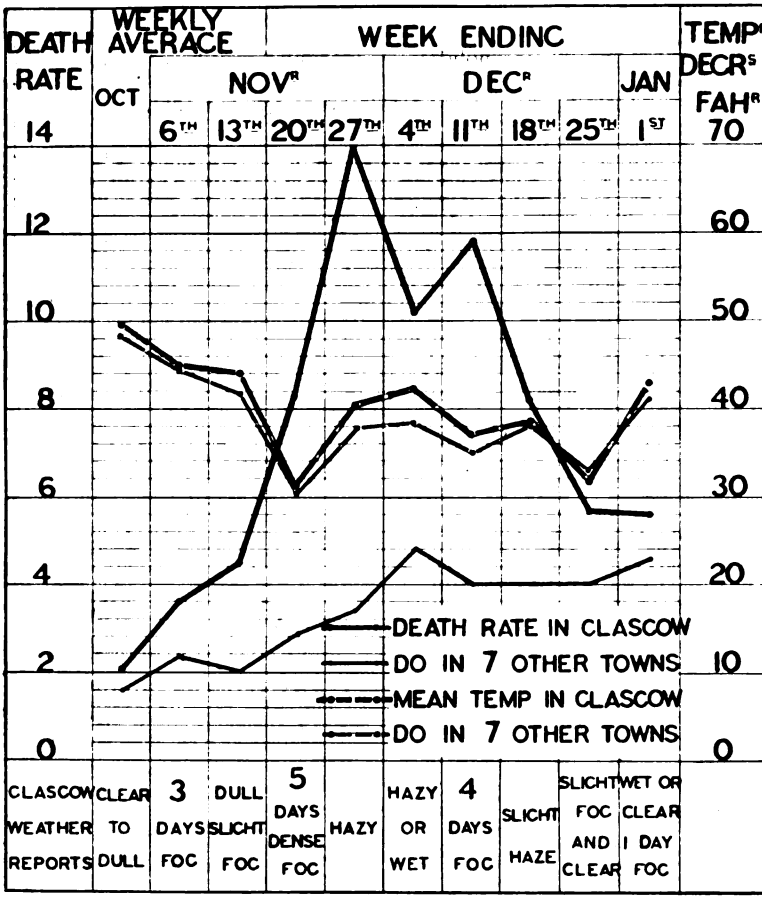

DIAGRAM II.

something more than cold, and as every other condition was similar, except the impurity of the atmosphere, I am convinced that was the cause.

After increasing the Glasgow death rate for November and December above the October rate in the same proportion as the other seven towns, there was still an excess over that increase of about 1,000 actual deaths, and those were mostly among the very young and the old; these excess deaths I attribute to the impure atmosphere that the population of Glasgow were compelled to breathe. This was an extreme example, but it indicates what occurs in a lesser degree in any district whenever the air is polluted, and probably the death rate from bronchial diseases in excess of that due to cold and damp will be in almost direct ratio to the amount of impurity. I have said nothing about the effect on phthisis or other forms of tuberculosis: owing to the lingering nature of this disease, weekly or even monthly returns would be unsuitable for comparison, but I have brought sections of two lungs to show you, one taken from a man who lived in the country and another from a man who lived in the town. From their appearance you can form your own conclusions as to which man was likely to have the most resistance to infection.

The drop in the death rates occurring in the second quarter of 1921, during the time of the coal dispute when the atmosphere of our cities was as clear as it should always be, is worth considering.

1920—DEATHS.

		Respiratory Diseases.	*All causes.*
First Quarter	..	1,021	4,371
Second Quarter	..	896	4,316

1921—DEATHS.

First Quarter	..	965	4,641
Second Quarter	..	476	3,619

The difficulty is that we cannot avoid this, for few people can go far from their business. Even when we take a holiday, we cannot avoid it. Here is a condition of air in one of our famous health resorts on a bright summer morning, just before breakfast time, and here is the condition of the atmosphere caused by the steamers which take us to it. By using an obsolete type o boiler they are throwing into a beautiful atmosphere many tons of unconsumed smoke. Unfortunately, we have to breathe the air that is around us, as no other source is available. We may bring the drinking water from great distances into the city from a source which is free from impurities, but we cannot bring clean air in, but are condemned to swallow it just where we are. Poisoning the atmosphere ought to be considered as criminal an action as poisoning a well.

When the Committee were in Sheffield, they were told that there were some processes that could not be carried on without excessive smoke. Admitting that that is so, should that smoke, after it has done its work, be allowed to escape into the atmosphere? I am of opinion that, as a matter affecting public health, it should not be permitted, and in the report I am a minority of one in recommending:—

> "That the Government should stimulate and, if necessary, subsidise research, with a view to discovering an efficient method of catching or consuming the smoke before it passes into the atmosphere. When such a method is found, its adoption by manufacturers should be made compulsory, and Local Authorities should be empowered to make a contribution, if they desire, towards the cost of installation and its maintenance."

I meant, that if it could be proved that catching or destroying the smoke necessary to a process increased the cost beyond that at which it could be produced in other countries in competition, then that increase should be paid to the manufacturers out of the Health rate, rather than allow the air to be polluted, to the injury of the health of the community. I believe that such cases would be so few as to be almost negligible.

The City of Glasgow spent a capital sum of about 2¾ millions and are paying annually about £300,000 in the treatment of sewage, that they may keep the River Clyde clean, as a dirty river injured the amenity of the city and district, although it did little harm to health. Should any city not contribute a little, if necessary, for the amenity of the atmosphere and the improvement of public health?

DISCUSSION.

Professor H. E. Armstrong, F.R.S., in opening the discussion, paid a tribute to the work of Lord Newton's Committee. If the results which the gentlemen on that Committee had achieved had not carried them very far, it was not through any fault of theirs in failing to give the necessary attention; it was the fault of the Ministry. He sympathised with Lord Newton when he said that he was disappointed in having had so little notice paid to his Report; he (the speaker) thought that, in a measure that was due to the way in which the results of the enquiry had been put before the public. The Report really gave very little information. It was full of black figures which apparently were references to answers of witnesses: he would like to ask why the evidence had not been issued.

The Chairman said he understood that the evidence, which amounted to an enormous volume, had not been asked for by anybody, and, in the interests of economy, it had not been printed. If there was a general demand for the evidence he had no doubt that the Department concerned would be obliged to produce it.

Professor Armstrong, continuing, said the evidence had been printed, as he had seen it and read it; but it had not been published. He felt justice could not be done to the Committee's work until the Report was before the public. The Chairman had complained of the use of raw coal. Everybody complained of the effects; but the coal fire was one of the most beautiful objects to be seen in unbeauteous London. There was nothing more inspiriting in its way than a coal fire, whatever the consequences of using it might be. It was a thing of beauty and a joy for ever. He had been on the deputation to Sir Alfred Mond—to which the Chairman had referred—and had been immensely struck by Sir Alfred's treatment of the subject; he had dealt with it in a practical way, on that occasion. Sir Alfred told the deputation: "These suggestions are all very well, gentlemen, but I know what are the practical difficulties, and I am not going to advocate premature action." That was the position at the present time.

At no very distant date, the smoke nuisance would be entirely disposed of; the way to do that was now being traversed; but the way to do it and the only way to do it was not that foreshadowed by the Chairman. The Chairman had foreshadowed throwing everybody

into the arms of the Gas Companies. The whole of the Committee's proceedings and Report seemed to be under the shadow of gas. With gas in its present condition of imperfection, and as the gas industry did not know where it was or where it was going to be five years hence (it only knew where it was not and where it had been), it was no good asking people to adopt gas.

Again, it was no good asking Englishmen to adopt the central heating system and to give up high temperature radiant heat. Therefore, the subject had to be developed further. The use of a smokeless fuel had to be developed, a smokeless fuel which could be used in an English ventilating grate. That smokeless fuel was on the way; it was close at hand. He had described it before the Society 18 months ago. It seemed to him that Lord Newton's Committee's reference was only half executed. The Committee had enquired into pollution of air by smoke; nobody needed conviction on that point; they were already fully persuaded. The Committee, however, had not enquired sufficiently into the ways of getting over the difficulty on the constructive side. The Committee had only dealt with the matter from the point of view of the gas interests. Also no one was put on the Committee to deal with the question from the scientific side. There was one chemist on the Committee, but he was a chemist who had given his attention to soot and not to constructive action in burning fuel. The Committee had not called upon people who might have given valuable evidence, such as Professor Bone, who was anxious to appear before them. Both Professor Bone and himself had been pressed upon the Committee, but neither of them had been asked to appear before it. The enquiry had not been carried sufficiently far on that side. That was the fault of the Ministry in appointing such an incomplete Committee. The Ministry of Health, in appointing the Committee, should have gone to the Society of Chemical Industry and asked for the nomination of, say, three fit and proper persons to deal with the matter. They should not only have appointed a chemist who had paid attention to smoke and nothing else. The problem should have been dealt with in a scientific manner. It was a disgrace that great coal users in Sheffield and other places should be wasting coal as they did at the present day.

Professor W. A. Bone, F.R.S., said the subject was one of great complexity and importance. Up to a certain point everyone was in agreement. The desirability—in fact, the necessity of—smoke abatement, from the point of view of health and so forth, was so far proven that it required no more evidence. Beyond that point, however, great differences of opinion were held on some of the technical issues which the Chairman had raised. He thought that some of the so-called facts put forward in the paper were open to considerable criticism. He questioned very much whether the solutions indicated in the Report which Lord Newton's Committee had presented were altogether practicable.

The problem of domestic heating was exceedingly complex. There was no doubt in his mind as to the unsuitability, for the heating of dwelling-houses, of central heating systems with low temperature radiators. Having regard to the peculiar conditions of our climate, and particularly the absence of radiant sunshine during the winter months, and the prevalence of dull leaden skies, everything pointed to the need of high temperature radiation. Therefore, we were chiefly limited to gas and solid fuel fires. The gas fire had been brought to a high degree of perfection, both hygienically and from the point of view of radiant efficiency, and if only gas could be supplied at a considerably lower price than it was at present, or than it seemed likely to be supplied at for some time to come, he thought the gas fire would present a good practical solution of a great part of the trouble. But the cost of running gas fires for long periods together made it, in many cases, almost prohibitive. Therefore, he thought that for the greater part of the problem they would have to come back again to the solid fuel fire. He hoped it would be a long time, if ever, before we parted with open fireplaces. He believed that the main solution of the problem lay in the direction of manufacturing and distributing, at much the same price of coal, a semi-carbonised smokeless fuel. Also, he thought that the problem of manufacturing domestic smokeless fuel was one which did not merely include carbonising the coal. Personally, he looked forward to the time when the solid fuel provided for houses would be a much more highly manufactured article than anything which had yet appeared. He believed the time was coming when they would remove from coal for domestic purposes a great part of the ash by flotation processes; that they would then carbonise a nearly ashless fuel in particular ways so as to get particular textures and obtain a fuel of the requisite degree of combustibility. The real problem was not merely smokelessness; it was one of rendering a fuel as ashless and smokeless as possible, and with the requisite degree of combustibility. That was not altogether easy, but it was a perfectly solvable problem if it was tackled in the right way. So far, too much attention had been paid to the question of smokelessness, and too little to the other factors; but he believed in the future they would begin to look at domestic solid fuel from a very different angle from what it had been looked at up to the present time.

With regard to smoke prevention in manufacturing operations, he did not at all believe in the methods which had hitherto been adopted, namely, penalising people by fines and the like.

He would like to see a legislative enactment made to the effect that every factory or works consuming more than a certain amount of coal in the year should be compelled to appoint a properly qualified fuel technologist on its staff. He would also like to see classes instituted to give information and training to those who stoked and ran boiler furnaces; that was a work which should be carried on throughout the country by the Technical Education Committees. Then he would like to see the practice established of paying stokers a bonus for keeping smokeless chimneys, and for getting good results. He thought such a system would be far more successful than one of penalties in curing the smoke evil. Personally, he was against prohibitive and restrictive legislation in regard to particular uses of fuel. He believed progress would be impeded in the long run if it were to be enacted that, say, nothing but gas was to be burned in houses. Great elasticity and freedom must be allowed in this country.

He would like to make one more suggestion of a practical kind. He believed it was referred to in Lord Newton's Report, and it was one in which he himself thoroughly believed. If a smoke inspectorate could be established throughout the country, somewhat on the lines of the Alkali Inspectorate, in order to assist manufacturers in solving the problem, it would be of the greatest benefit. He believed he was right in saying that the Alkali Inspectorate, which had been established many years ago, with many apprehensions and some opposition on the part of manufacturers, had proved itself, and was acknowledged by the manufacturers, to be a very valuable institution, and that it had saved this country a great deal of atmospheric pollution of a very bad type. He thought it had also saved the manufacturers money and it had been carried on at a very moderate cost, very unobtrusively but very persistently and successfully. He ventured to say that the establishment of a national smoke Inspectorate, who could advise and help manufacturers in the matter and conduct investigations unobtrusively, would probably, in the long run, be one of the most effective engines for accomplishing what everybody wished to see brought about.

Mr. F. Lloyd said that when he had appeared before Lord Newton's Committee, on behalf of the Sheffield manufacturers, Lord Newton had told him that no action would be taken by the Government, which would have any deleterious effect on the trade of Sheffield, without the manufacturers first being warned about it and consulted. In Sheffield they knew something about steel, and they knew that they could no more make certain classes of steel without smoke than cooks could make omelets without breaking eggs, and if any legislation on the matter was going to be brought in, manufacturers ought to be protected. All those things which Professor Bone had suggested as being desirable to adopt were already in force, and had been in force for years, in Sheffield. There had been more money spent in Sheffield on the question of reduction of smoke than in all the rest of the United Kingdom put together. Every large firm in Sheffield had its chemist. Sheffield University had a Fuel Research Board, and everything was being done that could be done in the matter of smoke abatement, not in order to keep the people's collars and linen clean, but on account of the simple fact that coal cost money.

Professor Bone, in reference to Mr. Lloyd's remarks, said he knew perfectly well that practically all the works in Sheffield had their chemists, but in his previous remarks he had not been referring to the ordinary metallurgical chemist, who had so much other work to do in the works that he could not pay attention to the fuel side at all. He believed there were very few firms who had fuel technologists specially attached to their staffs. He knew of one works which had a fuel technologist, and very beneficial results had accrued to that works thereby.

Mr. F. W. Goodenough said he would like, if he might, as representing the gas industry, to enter his modest protest against Professor Armstrong's attack upon the impartiality of Lord Newton's Committee. Those who had had the pleasure of giving evidence upon that Committee, and who had heard others give evidence, would agree that the Committee had been most searching in its enquiries, and had given every indication of its desire to arrive at the truth of the particular matter which they had investigated.

With regard to smokeless fuel, he thought he must quote the words of the poet: "Man never is but always to be blest." Smokeless solid fuel other than coke was always coming, but, so far, it had not come. The company with which he was connected had made a very serious attempt some years ago to produce and market a smokeless fuel, in competition with coke and coal, and they had found that, with all the resources at their disposal, they could not produce a solid smokeless fuel at a price which would tempt the public to buy it in competition with smoke-producing fuel, and they had had to abandon its manufacture because it had not been a commercial proposition. Professor Armstrong said that gas companies were not now where they had been. That was quite true. They had gone ahead. During the last three years the increase in gas appliances in the district of the country with which he was connected had been 100,000, no less than 50,000 appliances having been fixed in the last twelve months. Gas companies were rapidly helping to solve the smoke problem in London and in other parts of the country. Those who were old enough

to remember the fogs of 20 and 30 years ago would agree that the fogs of to-day were infinitely less horrible in their constituency than they were in bygone years, because the amount of smoke from domestic chimneys of this city was far less in volume now than it was a few years ago. Throughout the summer one could walk down road after road of residential property and not see smoke issuing from any single chimney at any time during the day, Sunday included. That, undoubtedly, had had no small influence upon the death rate of London, which had been steadily falling for years part.

He did not think that the Ministry of Health had completely failed to be affected by Lord Newton's report; in fact, he had evidence to the contrary. They had published in their special housing periodical, which was sent regularly to all housing authorities, all the necessary particulars for the construction of flues for the use of gas fires only instead of coal fires, pointing out the economies in the construction and building of houses which could thereby be effected. He did know that that had exercised a certain amount of influence upon local authorities in regard to the use of gas. The author had shown in his figures an efficiency of heating for solid fuel of 25 per cent. That was rather a misleading figure, if other considerations were not borne in mind. It was true that a coal fire might give 25 per cent. of its heat to a room during the hours it was burning if it was properly stoked, but a coal fire to be available when required had to burn for many hours when the heat was not required, and the true efficiency should be the total amount of heat that was given off by the coal fire in relation to the amount of heat that was actually required. That would bring the comparison between coal and gas very much nearer together than the figures of the author indicated.

The Chairman, in proposing a hearty vote of thanks to the author for his paper, said he would like to say, in reference to Professor Armstrong's criticism of his Committee, that that Committee had not been called upon to suggest what particular kind of fuel should be employed; it had been invited to consider the state of the law, and whether any extension of the law was desirable. With regard to the question of the coal fire, although he was not a scientific person, he thought he had sufficient sense to realise that one could not have, at the same time, the æsthetic beauty of a coal fire and also cleanliness. A choice had to be made between those two things. There was not much doubt as to what the choice of Professor Armstrong would be, but whether that would be the opinion of the majority of the audience or not he was not quite sure. Professor Bone had deprecated punitive legislation, or, if he had understood him rightly, any legislation of any kind whatsoever. He would like to ask Professor Bone how he thought any improvement would ever have been carried out unless there had been some kind of punitive legislation? It was a beautiful theory that everything could be done, so to speak, by kindness, and by attaching scientific gentlemen to all great undertakings; but probably it would cost those undertakings as much to pay the salaries of those scientific gentlemen, as it would cost them to pay any fines for disobeying the law. Mr. Lloyd had reminded him that he had given an undertaking that nothing would be done to prejudice the trade of Sheffield. He had no hesitation in repeating that assurance. He could not conceive that any Government would be foolish enough permanently to injure or cripple any important district in this country even for the sake of cleanliness. He did not think Mr. Lloyd need be under any great misapprehension as to what would happen; he (Lord Newton) was not of a very sanguine disposition himself, but he thought it would probably be a long time before anything was done, and that when it was done it would not be nearly so formidable as Mr. Lloyd anticipated.

The vote of thanks was then put and carried.

Mr. Smith briefly acknowledged the vote and the meeting terminated.

Professor W. A. Bone has sent the following additional communication upon the subject: In view of Lord Newton's remarks at the close of the meeting, I wish to make it quite clear that, although opposed to the imposition of penalties except in extreme cases and as a last resort (in which case they should be made exemplary), I would strongly support legislation of the right sort, such as (*a*) the establishment of a National Smoke Inspectorate on the lines of the existing Alkali Inspectorate, and (*b*) the compelling of every large industrial user of coal to appoint a fully qualified fuel technologist on his technical staff. Such measures as these would, in my opinion, be more beneficial than any proposals made by Lord Newton's Committee, whose report had indeed been disappointing. There need be no surprise that his Committee had signally failed to realise what are the essential elements involved in any successful campaign against smoke in an industrialised country like ours, in which large populations are concentrated in congested areas. Indeed, it may be doubted whether the Committee had sufficient technical experience: and, with the exception of a distinguished organic chemist who has made a special study of the composition of soot and atmospheric pollution by it, there was no one to give it authoritative guidance upon the science of coal and combustion. It seems to have run away

with the idea that in the domestic field the chief and most promising remedy for the smoke evil would be the extended use of gas, and it quite rightly heard a great deal of evidence from persons connected with the gas industry. But it seems to have insufficiently considered the question of the future use of smokeless solid fuel for domestic purposes, and to have lacked outlook in that important direction. Therefore I do not think that its conclusions ought to be considered as embodying the best informed opinion upon the matter.

In conclusion, I should like to put on record the fact that on 17th March, and 28th April, 1920, I wrote personally to Lord Newton, as Chairman of the Smoke Abatement Committee, asking to be allowed to give evidence, particularly on the domestic aspect of the problem, to which I had given considerable attention. But my request was not granted. Accordingly, I think it right now to reproduce the following two paragraphs from my said letters so that the public may know what views I wished to lay before the Committee, had the opportunity been afforded me:—

> "As the result of considerable thought "and investigation on the subject, I have "come to the conclusion that the solution "of the problem of domestic smoke must "be sought for chiefly in two directions, "namely (a) the manufacture of a smokeless "low temperature distillation 'semi-coke' "for combustion in our open fireplaces, and "(b) the extended use of gas fires in rooms "which require to be heated occasionally "only. I believe that were it possible to "manufacture and distribute generally a "suitable smokeless semi-coke, the open "fireplace would become not only the "healthiest but much the cheapest form of "supplying radiant heat to living apartments, "which, from a physiological point of view "is highly desirable. The use of gas fires "for rooms requiring to be heated all the "day during the winter is, in my opinion, "out of the question because of the prohibitive "cost."

And again, because of the fact that one witness connected with the gas industry is reported to have actually suggested to the Committee, that, from the point of view of smoke abatement and of national economy, Parliament should restrict the use of coal in open domestic grates, either by rationing coal or by forbidding the use of more than one open fire grate per house, I remarked:—

> "It is, of course, obviously in the interests "of the gas industry that the open fireplace, "which undoubtedly produces radiant heat "at a lower cost than gas fires, should be "prohibited, in order that it may secure a "comparative monopoly of the domestic "heating business; but I feel sure that such "a suggestion would be strongly resented "by the public generally as an unwarranted "interference with their freedom of choice, "and that, on both scientific and economic "grounds, it ought not to be entertained."

NOTES ON BOOKS.

British North Borneo. By Owen Rutter. London, Bombay and Sydney: Constable & Co., Ltd. 21s.

Fifty years ago the territory now known as British North Borneo was ruled by two native princes, each of whom claimed sovereignty over the other's dominions. The coasts were infested with pirates, the highlands with head-hunters. To-day, according to Major Rutter—who has resided many years in the country, first as a Government Officer and afterwards as a planter—the Borneo seas are as safe as the Solent and the jungle paths as secure as Pall Mall. This rapid change is due to the work of the British North Borneo Company and to the District Officers, of whose ability and tact the author speaks in terms of the warmest praise.

Major Rutter gives an interesting account of the establishment of this British colony, due in the first instance to an adventurous Scottish engineer, William Clarke Cowie, and secondly to Sir Alfred and Mr. Edward Dent, both of whom are Fellows of this Society, and the latter a member of the Council. The whole story is only excelled in romance by the tale of Sarawak, whose acquisition by Rajah Brooke is one of the most interesting episodes of the colonial history of the nineteenth century.

It is difficult within the limits of a brief review to know which aspects of the book to select for mention. The author writes in attractive style of the native population—for whom he appears to entertain a most friendly regard — of the administration, punitive expeditions, the jungles, agriculture, minerals, native customs, folk-lore and methods of living, travel, and a general account of life in North Borneo. Each of these chapters is full of interest, and much valuable information is given as to the resources and possibilities of the country. These are evidently very great. Already numerous estates have been formed for the cultivation of rubber, tobacco and coconuts; a hundred miles of railway have been built and the interior is being opened up by the construction of bridle paths. For detailed particulars on these points, many of which were discussed by Major Rutter in the paper recently read by him before the Dominions and Colonies Section of the Society, the reader must be referred to the book itself. This abounds in topics of very varied interest. One may, perhaps, mention the description of the remarkable limestone caves where are found in vast quantities the edible bird-nests, the sale of which in 1920 realised the respectable sum of £25,985. The collection of these, often at a height of several hundred feet from the ground,

is at least as perilous as the "dreadful trade" of the samphire gatherer. Even more terrifying is the account given of the taking of a wild bees' nest by probably the only European who has attempted the task. The nest was at the top of a tree, about 120 feet high. The hunter was advised to climb stark naked, "because if you wear clothes, the bees in thousands work their way in and may sting so seriously as to cause you to lose your hold in trying to beat them off, and a drop means certain death." The absence of clothing in the case described did not save the hunter from terrible punishment, which seemed a disproportionate price to pay for sixty pounds of honey.

BRAZILIAN TIMBERS EXPORTED.

Brazil is recognised as one of the richest countries in the world in timber for building and industrial purposes. There are over 300 varieties of this class of wood existing in the State of São Paulo alone. Some of the harder and more durable woods of Brazil have been known to form a part of structures more than a century old, and it is not uncommon for many species of Brazilian timberwork exposed to the weather and action of water to endure for 50 years.

In addition to the immense tracts of timber of various kinds existing in Brazil there are innumerable trees which yield secondary products useful in pharmaceutical and veterinary science, while the bark and leaves of many others are used for tanning purposes.

With the exception of Parana pine, cedar is exported from Brazil in the largest quantities. Brazil wood is also exported, most of it going to the United States. It is a bright red wood, with dark patches, fine grain, and hard to carve, and is used in shipbuilding, very high-class cabinet work, and other work for which a wood with a good, smooth polishing surface and strengthening are required. Jacaranda, a very valuable wood, suitable for first-class cabinet-making and exterior work, for bridges and dams, and for shipbuilding and railway ties, and which is one of the important woods in the Brazilian furniture industry, is also exported in small quantities. Massaranduba wood is exported in small quantities to England and Portugal.

It is interesting to note, however, writes the United States Assistant Trade Commissioner at Rio de Janeiro, that Parana pine comprises about 75 per cent. of the total Brazilian timber exports, in spite of the fact that by far the greater part of its timber imports is composed of similar wood from the United States, viz., southern yellow pine. In 1918, for example, exports of Parana pine amounted to 16,825,753 milreis, of which 10,750,490 milreis went to Argentina and 6,075,263 milreis to Uruguay. When it is remembered that these two countries together in 1910 only imported this pine to the amount of 148,000 milreis, it is easily seen how important has been the development of this industry for Brazil. It is estimated that the use of Parana pine has increased at least 50 per cent. since 1917. As soon as methods of seasoning Parana pine are introduced whereby the difficulties of warping and checking can be eliminated, the market in Brazil for imported yellow pine, will be adversely affected. The large supplies of this wood going to Argentina and Uruguay have been used in the main for boxes, fences, and similar uses other than construction purposes.

NEW PROCESS FOR EXTRACTING NITRATE OF SODA.

According to a report by the United States Consul at Iquique, official tests of the Junquera process for the extraction of nitrate of soda have just been held at the Oficina Galicia, near Iquique. They were witnessed by many men prominent in the nitrate industry, and the impression is general that the inventor has in large part made good his claims. Certain changes and improvements in the plant as installed are obviously necessary, but these are considered matters of detail, and there is a disposition to recognize that a new invention has been made which, when improved, may revolutionize the industry.

The inventor claims the following as the results that will be consequent upon the general adoption of his process:

1. An increase of ten or twenty fold in the nitrate riches of the Republic, as caliches with nitrate content as low as 10 per cent. can be worked profitably.
2. Assurances to the Government for many years of the collection of export taxes at the present rate without hurting the industry.
3. Cheapening the cost of Chilean nitrates so much that the competition of artificial products will be postponed for many years.
4. Plant installations can be made with one-half the expenditure now necessary.

In the Junquera process the material is ground to pass through a ¼-inch mesh and is then highly heated. It is placed in a battery of eight gyratory drums, each 6 feet in diameter, and having its edge made of filter cloth. Water is forced into the centre of the first drum and is driven by centrifugal force through the material and out of the drum's edge, where it is caught and passed in rotation through all the drums. Leaving the eighth and last it is saturated with nitrate and is allowed to cool and deposit its nitrate contents in settling tanks.

In the test just concluded, working with material of 12 per cent. content of nitrate, the extraction was said to be total and the consumption of oil fuel only 9½ kilos per ton, but it should be noted that this test was made with fresh water and that the various weak solutions were not worked out as they would have to be in actual practice.

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FRIDAY, DECEMBER 29, 1922.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

NOTICES.

NEXT WEEK

WEDNESDAY, JANUARY 3rd, at 3 p.m. (Mann Juvenile Lecture.) CHARLES R. DARLING, F.Inst.P., F.I.C., "The Spectrum, its Colours, Lines and Invisible Parts, and some of its Industrial Applications." (Lecture I.)

The lecture will be illustrated with experiments.

Special tickets are required for this course, and no person can be admitted without one. A few tickets are still left, and these will be issued to Fellows who apply for them at once.

BICENTENARY OF SIR CHRISTOPHER WREN.

The Council have nominated their Chairman, LORD ASKWITH, K.C.B., K.C., D.C.L., to represent the Society on the Grand Committee appointed by the Royal Institute of British Architects to carry out the arrangements in connexion with the celebration of the Bicentenary of the death of Sir Christopher Wren.

BINDING COVERS FOR JOURNALS.

For the convenience of Fellows wishing to bind their annual volumes of the *Journal*, cloth covers can be supplied, post free, for 2*s*. each, on application to the Secretary.

LIST OF FELLOWS.

The new edition of the List of Fellows of the Society is now ready, and copies can be obtained by Fellows on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.

DOMINIONS AND COLONIES SECTION.

TUESDAY, DECEMBER 5TH, 1922.

MR. EDWARD DENT, M.A., in the Chair.

THE CHAIRMAN, in introducing the author of the paper, said that Major Rutter was an official in Borneo up to the time of the War, when he retired and joined the Forces. He had just published a very interesting book, which was probably the standard work on North Borneo. Three papers on Borneo had been previously contributed to the Society, one as far back as 1884 by the late Mr. B. Francis Cobb; the second in 1903 by Mr. Henry Walker, and the third in 1912 by Mr. Leonard Lovegrove.

The paper read was:

BRITISH NORTH BORNEO.

By MAJOR OWEN RUTTER, F.R.G.S., F.R.A.I.

At any time a person of my own modest accomplishments would rise with diffidence to address so distinguished an assembly as one composed of Fellows of this Society. But I rise with all the greater diffidence this afternoon when Mr. Edward Dent is in the chair. For it is Mr. Dent, and not I, who should address you on the subject of North Borneo, because it was he and his brother, Sir Alfred Dent, together with a little band of adventurous gentlemen, who first thought of founding a British colony in that far away land that lies on the fringe of the China Sea.

The story of how North Borneo became British reads like a page taken from romance. Fifty years ago the country was under the nominal sway of two native princes, the Sultan of Brunei and the Sultan of Sulu. Each claimed sovereignty over the other's territory, but neither troubled much to enforce his claim, for in those days it was a land where rulers did not care to go about on royal tours. All along the coasts were nests of pirates; in the hills lived communities of head-hunters. There was no

semblance of organised government. The cheapest thing in Borneo was human life.

It does not sound the sort of country in which one would want to settle down. Yet that was probably the very reason why it attracted to its shores a young Scots engineer named William Clarke Cowie, who afterwards became Chairman of the British North Borneo Company. Mr. Cowie went into partnership with the Sultan of Sulu in a trading enterprise. He made a base at Sandakan, the present capital, saw the economic possibilities of the country and determined that it should become British. The acquisition of a territory the size of Scotland was, however, too great an undertaking single-handed, even for Mr. Cowie. A certain Austrian baron, Overbeck, and the Dent brothers became interested in his projects, and at last, after many and tedious negotiations, and under the very noses of at least three European Powers which had long cast covetous eyes on the country, Alfred Dent and his friends acquired the cession of North Borneo. These enterprising gentlemen were not even content with obtaining one cession. As both Sultans claimed the territory and there was no court of arbitration, they solved the matter by getting a cession from them both. Thus Alfred Dent became uncrowned king over a vast and little known land and with powers of life and death over a less known people. It was a bloodless conquest and, unlike many of our territorial acquisitions, a perfectly legitimate one. The final deed was signed on January 22nd, 1878, in the Sultan of Sulu's palm-leaf palace. His Highness, to mark the historical event, gave a dinner-party; the plates were mother-of-pearl shells with pearls attached to them, and at the close of the evening the Sultan asked each guest to keep his plate in remembrance of the occasion. He seems to have been a model host.

That night laid the foundations of the British North Borneo Company which administers the territory under its President, Sir West Ridgeway, to-day. I have no time to do more than outline the process by which the country has been transformed. When the British pioneers took possession of it, North Borneo was a land of disorder, a tropical wilderness in which a man went about with his life in his hand. There was no European enterprise of any kind. Save for the rice fields of the native tribes the jungle was everywhere.

Look from that picture of 44 years ago to the picture of North Borneo to-day, and what do you see? The pirates are no more and the head-hunters have ceased to raid. Their descendants are fishermen or farmers; many of them have joined the native police. To-day the seas of Borneo are as safe as the Solent and its jungle paths no less secure than the pavement of Pall Mall. The people live at peace. There are Government Stations all over the country, little towns have grown up, rubber, tobacco and coconut estates have been made. Harbour works have been constructed. The hill country has been opened up by means of bridle paths. There are over 100 miles of railway, and, although the country has suffered in the past for lack of roads, these are in the making now.

Who are the men who have done all this? Who are responsible for the change? Not, as the Chairman would be the first to tell you, the Court of Directors, not the Governors, not the Heads of Departments. They have all done their share, but, just as the War could never have been won without its subalterns, so North Borneo could never have been made without its District Officers. The District Officers were the men who explored the country and opened it up for peaceful trade. They travelled on foot through the dense jungles; they paddled up and down the rivers in native boats. They lived solitary lives in their outstations, often many days' march from the nearest white man. They made friends with the native tribes, induced them to abandon their feuds, gave them the protection of a settled Government and taught them the benefits of living under a just and benevolent administration. They put up their own offices, barracks and houses, they made the bridle paths which link up the outstations to-day, they erected telephone lines from the West Coast to the East. They dealt out justice, they pursued rebels and outlaws; they fought epidemics of cholera and small-pox. Those who have followed them maintain their traditions. A District Officer to-day is a Magistrate, Police Officer, Collector of Revenue, Postmaster, Gaol Superintendent, Customs Officer, Doctor, and many things besides. Outside the country few know the work he does, but that matters little, for in his district and among the natives that he comes to love he finds his reward.

Now this learned Society is not primarily

concerned with ethnology. Yet I feel that you will forgive me if I try to tell you something of the natives of North Borneo with whom the District Officer has to deal. I do not think there can exist any more pleasant people. Even when they are rogues, they are pleasant rogues; even when they are ex-head-hunters they are very likeable. And the further one goes from civilisation the more likeable do they become.

For general purposes they may be divided into three groups—the people of the coast, the people of the plains, and the people of the hills. Each group has its own characteristics and mode of life. The coast natives are mainly Bajaus, Sulus and Illanuns; they are Mohammedans and descendants of the pirates of old. For the most part they are sea-gipsies; their boats take the place of caravans and they make their living from the produce of the sea. In some districts they have abandoned this wandering existence, but even when they build houses they usually build them over the water upon the sea-shore or the river banks. Some of them, however, are accomplished horsemen. They hunt deer on ponies, and they formed the mounted bodyguard on the recent visit of the Prince of Wales to North Borneo.

The inhabitants of the plains are the Dusuns, who are the backbone of the native population. They are a race of farmers, law-abiding and industrious, and cultivate the rice which is their staple food.

Some of the Dusuns come into the hill group and with them are the Muruts. The latter are the most primitive, and, in many ways, the most interesting of all. They live in villages composed of one or perhaps two houses 200 or 300 feet in length, perched high upon a hill to be out of the way of raiding parties. For it is only within the last few years that they have abandoned head-hunting, and even now, if you sleep a night in one of their villages—and they are most hospitable and always glad to give you the shelter of their roof—you will see a cluster of smoked human skulls dangling from the rafters above you, like so many ripe coconuts. The head-hunting they used to practise was the outcome of feuds between villages. It was a kind of war and it was part of the District Officer's business to arrange the peace terms. These were sealed by bathing in the blood of buffaloes and planting stones as witnesses of the oaths of peace. It was not always easy to get them to come to terms with each other. I remember there was a recalcitrant chief once who sent a message to the Government Station that if the District Officer came near him he would make hair-pins out of his shinbones and gouge his eyes out, as he had long wanted to know what the eyes of a white man were really like. But when, some time afterwards, the District Officer did get to his village, he found him a mild-mannered person and settled his feuds without difficulty.

Under the administration of the Chartered Company the natives are as well treated as any in the Empire. I say this with absolute conviction. Their interests are always safeguarded and their customs respected; the taxes they have to pay are not heavy; they are treated with sympathy and understanding—and the Government is at pains to get them all vaccinated. At the present time it may be of interest if I mention that once during a small-pox epidemic, when I was in the Civil Service, with the aid of a native lance-corporal, a penknife and some tubes of lymph, I vaccinated over 1,000 people—and among those there was not a single case of recorded small-pox, although the disease was raging through the district like a fire.

Among such people as these a District Officer's life is full of interest and so worth the living. There is much to do and every day there is something different. There are also many practical advantages of living in North Borneo to-day, not only for the Government Officer but for civilians too. The chief is that North Borneo is at the present time one of the least expensive countries in the world. To begin with, there is no income-tax. The only serious tax which hits the individual is a duty on imports ranging from five to fifteen per cent. Railway fares have not been increased since 1914. Clothes cost very little, for white drill suits are made by the Chinese tailors for £1 and canvas shoes for ten shillings a pair. Servants' wages vary between £2 and £3 a month. Whisky may be had for 8*s.* 6*d.* a bottle and cigarettes are cheaper than in England. Tinned provisions are expensive, but fresh fish, meat and vegetables are cheap and plentiful on the coast, while although the happy days when fowls cost 2½d. are gone for ever, they may still be bought for a shilling or eighteen

pence. Except in the towns fuel may be had for the gathering and there are no water rates. There are no strikers, no agitators, no remnants of war-time restrictions.

Of course, there are drawbacks too. North Borneo is the other side of the world, to be reached only by an expensive journey. For most people leave is difficult to get until after four years' service. Save in the little towns of Sandakan and Jesselton neighbours are few, life is lonely, and the amenities of civilisation are rare. There are no luxurious hotels, as yet one cannot motor for many miles, and except on the West Coast there are no railways. The climate, although exceptionally healthy for the tropics, has the usual trials of a hot country, there are no seasons, for Borneo is a land of eternal summer, and there are no cool stations in the hills as yet. As long as he takes plenty of exercise, however, there is no reason why a man should not keep perfectly fit. On the coast cricket, tennis and golf are played; there are football grounds in every Government Station and on nearly every estate, and the game is very popular with the natives, who kick as well without boots as with them. The lonely outstation man has riding and big game shooting; deer and pig abound everywhere, wild cattle are fairly plentiful and if a sportsman likes to work hard for them there are elephants and rhinoceros.

From the point of view of its future prosperity, North Borneo is peculiarly well-situated in the Eastern Seas. It lies 800 miles from Singapore, 1,000 from Hong Kong, 600 from Manila and 1,500 from Port Darwin. Steamers from all these places call regularly at its ports, though it would be a great boon to the country if Sandakan and Jesselton could be made ports of call for steamers running regularly from Europe to the East. It has several excellent harbours, in two of which—Sandakan and Cowie—the whole British Navy could lie without being overcrowded. It is well watered, especially on the east, where the rivers, the longest of which is the Kinabatangan, are navigable for many miles, and form the highways of the land.

The formation of the country, speaking generally, consists of a belt of plains near the coast, then a zone of low hills which gives way gradually to a region of highlands as the interior is reached; these culminate in the superb granite mass of Mount Kinabalu, which rises black and sheer, with beetling peaks, nearly 14,000 feet, and is the loftiest mountain of Malaya.

The natural resources of this great country fall mainly under three heads—those of agriculture, forests, and minerals. I give them as they stand in order of importance to-day. So far North Borneo has been an agricultural country; the economic prosperity it has attained is due to the suitability of its soil for growing any tropical product. In fact, as far as I have been able to discover, it will grow anything but onions.

At the present time rubber is the chief form of commercial cultivation; tobacco and coconuts come next. The rubber boom of 1909 came at a very opportune moment for North Borneo, whose fortunes were then at a low ebb. Mr. Cowie, who was then Chairman of the Company, was able to attract capital to the country by holding out two concessions—the remission of export duty on rubber for fifty years and a dividend of 6 per cent., guaranteed by the Chartered Company, which was to be repaid when the estates concerned began to show a profit. The scheme worked well. Several rubber estates came into being and prospered and out of twelve companies which received the guaranteed dividends nine have already paid back their advances in full. The prevailing rubber slump has hit companies operating in North Borneo hard as it has those elsewhere, but only one estate of any size has had to close down, and this failure was due as much to badly selected land as to the adverse conditions of the market. At the present time rubber estates in North Borneo, although worse off in one way than those in the Federated Malay States, are better off in another way: it is true that the slump came at a time when their shareholders had reason to hope for the handsome dividends which the F.M.S. companies had been paying for many years, but it is also true that in evil times Borneo companies can look to the Chartered Company for assistance when others would look to their Governments in vain. For the subsidiary concerns in North Borneo are essential to the well-being of the Chartered Company: they mean increased population, increased development, increased trade and, therefore, increased prosperity. As a matter of business and, as Sir West Ridgeway said recently, "not because of their beautiful eyes," the parent company cannot afford to let its children fail for want of a few thousand pounds. Many a company which has been helped out of its

difficulties in the past is now once more in a flourishing condition, and it is the settled and approved policy of the Court of Directors that as long as a subsidiary concern has a reasonable prospect of recovery it will be assisted. At a time when rubber is faced with the most serious crisis in its history this help may be the salvation of many Borneo estates.

Before the coming of rubber, North Borneo's chief agricultural asset was the wrapper-leaf tobacco; in fact, North Borneo and Sumatra are the only Eastern countries in which the peculiar conditions necessary for the cultivation of the wrapper-leaf—that is, the outside leaf of the cigar—are found. But at the best of times tobacco planting is a gamble, success being mainly a matter of the right rain at the right moment. There are still three fairly large companies in the State, but the industry has waned rather than progressed, although there are considerable areas of suitable soil available.

It is strange that hitherto coconuts should not have attracted more attention than they have. The palm grows as well in certain parts of North Borneo as anywhere in the world. Yet there are only two companies planting on a large scale, though many smaller estates exist. Coconuts have been called the "Consols of the East," but while they are as safe in normal times, they can be made to yield a considerably higher rate of interest.

No other tropical product is cultivated commercially to any extent, although it has been proved that coffee, hemp, indigo, sugar, and the oil palm will grow. Some interest is being shown in the latter, and to encourage it the Chartered Company is granting land without premium and rent free for five years. Proposals have also been made lately for planting Arghan fibre, a new product which has been introduced to the commercial world by Sir Henry Wickham.

It is an interesting fact that the world's great tropical cultivations, like the world's great empires, have risen to a zenith of prosperity only to decline. The coffee of Ceylon is an example. Rubber will undoubtedly recover from its present position, but it may be that a new era in the history of planting is about to dawn. If so, it will be well for North Borneo, for it will come at a time when the Company has decided on a definite programme of development.

Coming to the country's second great natural resource, the forests, there are signs of prosperity. The commercial timber in North Borneo is almost inexhaustible, but for many years lack of capital and difficulties of transport prevented it from being worked extensively. Recently, however, a new undertaking, the British Borneo Timber Company, in which the Chartered Company took a large financial interest, was organised and given a monopoly to export timber from the State. It has started operations on a large scale with an up-to-date sawmill at Sandakan, the centre of the lumber trade, and as it is bringing timber into the market at a time when the world's resources are low, its future should be assured. In fact, in his report for 1921 the Governor stated: "Markets are in sight for every foot of timber Borneo can produce."

North Borneo's third asset, the minerals, at one time seemed to offer the greatest possibilities of all. With a young country this must always be so. But the optimists of the early days have so far been doomed to disappointment. Gold is known to occur in the alluvial deposits of the great rivers, but a parent reef has never yet been struck. Other minerals have proved equally elusive, with the exception of coal, which is worked by a British company on the East Coast. Hopes have been raised, only to be dashed, especially in the case of oil, for which at the present time a Japanese company is prospecting on the West Coast and a British Company on the East. Nevertheless, other parts of the island have long proved rich in oil and gold and diamonds, and the area to be searched is so extensive that treasures may still be waiting for a discoverer.

From this brief description of North Borneo it will be seen that much has been done by the Administration. But much still remains to be done. Development has been slow. Increased population is one of the country's pressing needs, and even to-day not more than one per cent. of its vast expanse has been opened up. For this, as it seems to me, it is not fair to blame the Chartered Company, any more than it is fair to blame a city clerk for not building a palace in Park Lane. The whole thing is simply a question of money. The Company's wealth is limited and the amount paid out in dividends in forty years shows that its shareholders have not had money which ought to have gone back into the country.

Increased prosperity will come. At present I cannot do better than describe North Borneo as a land of possibilities. I have tried to indicate some of the planting, timber and mineral possibilities. But they are not all. Few industrial concerns exist; the only printing press is controlled by the Government; the only newspaper a Government organ, which appears twice a month. The rich fishing and sago industries are in the hands of the natives and Chinese. There is no European or American store. There is no canning factory. The only rattan furniture is that turned out by the prisoners, although the material abounds in the jungle. The Government owns the only ranch. The vast tracts of nipa palm from which sugar and alcohol can be manufactured are still untapped. I believe that a company has recently been formed to make socks out of tree bark from Sarawak. Well, there is plenty of tree bark in North Borneo. These things, and much else besides, await enterprise great or small.

DISCUSSION.

[The paper was illustrated by a very beautiful film depicting a trip through North Borneo by an American gentleman and his wife, Mr. and Mrs. Martin Johnson, and also by a film dealing with the visit to Jesselton of the Prince of Wales in the course of his tour in the Far East.]

REAR-ADMIRAL FREDERICK C. LEARMONTH, C.B., C.B.E., said he was fortunate enough to have been in Borneo four times, on two occasions for rather lengthy periods, which, for a naval man, was somewhat unusual. As a gun-room officer he was there not long after the signing of the Charter, the country then being in a very undeveloped state. Kudat was then the seat of Government, and he could remember that, when he was playing lawn tennis at Government House, he saw what they thought were monkeys on the branches of the trees, but they proved to be ourang-outangs. That would scarcely be believed in these days. In 1888 he was in the ironclad which conveyed that famous administrator, Sir Hugh Low, who was deputed by the Colonial Office to establish the Protectorate at Brunei and in British North Borneo. As Major Rutter mentioned in his admirable book, Sir Hugh Low was one of the first to ascend Mount Kinabalu in 1851. In 1891 and 1893 he (the speaker) was on a ship whose mission was to survey what was then a *terra incognita* the East Coast of British North Borneo, Darvel and Sibuko Bays, the latter better known now as Cowie Bay. At that time there was no reliable map or chart, and Darvel Bay was so unknown that in one of his earlier missions of survey he was detached for the long period of three weeks to find the way about in a sort of reconnaissance. The region was strewn with coral reefs, and on one occasion the ship went ashore in trying to find an anchorage: it was only by fine seamanship that she was got off very shortly without injury, although she had heeled right over. Coming to recent years, he was again in North Borneo when in command of a surveying ship, his object being to carry out a survey of a large stretch of coast between Jesselton and Kudat. They had to delineate more clearly Cowie Harbour, where a large number of ships could find room in deep water. A survey party were able to ascend Mount Kinabalu. This was no great mountaineering feat, but Kinabalu had not previously been climbed in large numbers. The mountain was 13,455 feet high, and his particular duty was to co-ordinate and complete all the survey work that had been done during many years, from a map-making point of view. It was necessary to wait for fine weather and a large amount of material had to be carried. He was accompanied by several of the Chartered Company's officers, without whose very willing help it would have been impossible to proceed at all. The party slept near the summit for five nights. It was a clever piece of work on the part of the district officers to get the natives to stay at that height: a thing they had never done before, as there were supposed to be many spirits on the mountain. The party were able to heliograph and signal to distances over 150 miles in the clear atmosphere after the heavy rain, and to co-ordinate the various sections of the map. If the War had not intervened he thought the Chartered Company would very likely have continued that work, as a correct map of British North Borneo was still very much wanted. The mountain being only 30 miles from the coast, was a great asset to the country, as there were great possibilities of establishing a health resort in the surrounding hills. The harbours in the country came into prominence at the Washington Congress, and were of very great value, especially Sandakan Bay, Marudu Bay, Cowie Harbour and Darvel Bay. They were sheltered ports and some would harbour a great many ships. The difficulties of improvement in navigation were chiefly financial. Access to the ports was not always available except by day, and lighthouses were costly, especially in such a country, but they would come in good time. Those who were responsible for the country had its welfare very much at heart. He should like to congratulate the Court of Directors on the Prince of Wales's visit.

Mr. A. C. Pearson, C.M.G., late Governor of North Borneo, said he had found little or nothing to criticise in the paper, and he could only congratulate the author on having delivered a very able address before a critical audience, because there were many present who perhaps knew as much about the country as Major Rutter; he himself had been there for 25 years. Major Rutter's knowledge of the country was wonderful considering the few years he had spent there. It was knowledge gained from personal experience, as well as deep research in the few scattered books which had been written about British North Borneo. The Prince of Wales was unable to visit Kuching, the capital of Sarawak, largely because of the tides, and North Borneo considered itself very much honoured in inducing the Rajah of Sarawak to visit North Borneo with the Prince, because it was, he believed, the first time that a Rajah of Sarawak had set foot on North Borneo soil.

Sir Charles Metcalfe, Bt., in proposing a vote of thanks to Major Rutter for his lucid and interesting paper, said that, in spite of his enthusiasm, he had been perfectly impartial and fair, and had shown the drawbacks as well as the advantages of the country.

Mr. Bryon Brenan, C.M.G., seconded the motion, which was carried unanimously.

FIFTH ORDINARY MEETING.

Wednesday, December 6th, 1922.

Mr. Laurence Currie in the Chair.

The Chairman, in introducing the lecturer, said the paper which Mr. Chubb was about to read was one which must be of great interest to very many people. The ingenuity which had been displayed in protecting property recently had been very great. As burglars had become more scientific so also had the makers of safes. Unfortunately, there was a tendency for crime to increase, so that everybody must welcome the precautions which science had placed in their hands.

The paper read was:—

RECENT DEVELOPMENTS IN THE MANUFACTURE OF SAFES AND STRONG ROOMS.

By Emory Chubb, M.I.Mech.E.

May I first thank you for according me the privilege of addressing you this evening? Apart from the historical antiquity of your Society, the present occasion is one of peculiar interest to me as my grandfather and also my father have both addressed you, within the last seventy years, on the subject that is before us this evening. In the more recent paper given you by the late Mr. H. W. Chubb, considerable attention was paid to the early growth and development of the art of lock making, but this evening I intend to devote the greater part of my remarks to the more modern aspect of this question of security. After explaining certain factors which influence us in design, I propose to show you a film which will demonstrate the practical and detailed construction of what I believe are two of the finest security units yet built in this country. In order, however, that you may the better realise developments which have taken place, I will for a few moments refer to the art and craft of the mediæval locksmith and safe-maker.

From the picture on the screen, which illustrates some good examples of mediæval craftsmanship, you will realise by comparison the influence of modern development, for the 20th century key is an object of utility rather than a thing of beauty. The worker is being affected in this as in many other trades where art has almost entirely disappeared, and the craftsman, in the old and accepted interpretation of the word, is being replaced by modern machinery and manufacturing methods. From many points of view this change is to be regretted, and it is the duty of the employer imperceptibly to guide the intelligence of his men in such a way that in spite of having withdrawn much incentive to individual originality and thought he does not convert them into human machines. Fortunately, in this trade, there will always be employment for the highly skilled workman, as there are certain operations where even the greatest mechanical accuracy is finally dependent on the skill of the fitter to piece the work together.

In mediæval times the progress of art metal work was largely exemplified in locks and keys and what are called finger plates for doors. In certain instances the lock-plates became fan-shaped owing to the employment of long springs in their mechanism, and here we see the influence of utility or necessity reflected in the art of the period. Some lockplates had most elaborate designs, a very favourite one being a conventional tree or vine shaped

in such a manner that the branches converged on the keyhole and acted as a guide to the key for use at night time, or when for other reasons it might be difficult to find the keyhole. One of the most noted locksmiths was a Frenchman, named Mathurin Jousse, who lived in 1627, but as with celebrated painters much of the work ascribed to him was probably carried out under his directions by apprentices. The picture before you illustrates certain types of locks of this period, many of which were fitted to strong wooden boxes or chests.

You now see a very good example of the banded chest or safe. The actual photograph was taken of the safe at present in

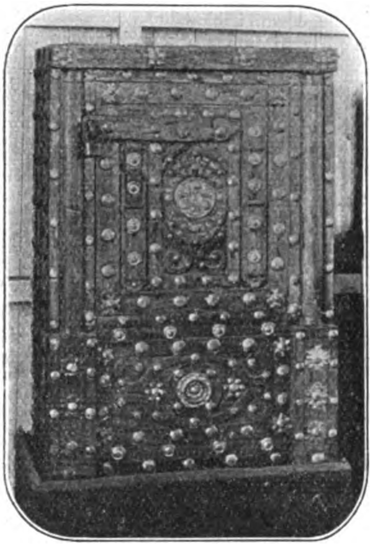


FIG. 1.—An old Banded Chest (probably Spanish).

use at the Customs House at Callao in Peru, and was probably left there by the Spaniards. Some two years after I had seen this safe I came across one identically the same in use in a jeweller's shop in Corfu. Another interesting safe is one I purchased a few weeks ago from a bookmaker at Luton. He informed me it had been dug up in his back garden. It is certainly of antique design and I presume that the gentleman in question did not consider it of sufficient strength or size to protect the proceeds of his calling.

Let me now bring you to the more serious work involved in the manufacture of security appliances. This in itself is, to my mind, a subject of inexhaustible interest, and this evening I shall only be able to touch on the fringe of some of its aspects without telling you of the reasons which compel us to design on certain lines.

The position in which we now find ourselves has been evolved largely through the progress of metallurgical science, which has made very rapid strides during the last twenty years. An indirect result of the war has been to spread a knowledge of the use of explosives and concentrated heat in many quarters where previously their powers were unappreciated.

No secrets are given away when I tell you that attacks made with the help of jemmies, wedges and drills are out of date so far as modern security work is concerned, as perusal of the daily papers will often show.

Before describing the technical developments which have taken place during the last few years, I should like to put before you some of the difficulties with which the Safe Designer has to contend. Let us suppose that the installing of a new strong room or heavy safe is being contemplated. The prospective owner will be confronted with two questions—the first, what will be the value of the contents? The second, what will be the risk from environment?

There is no doubt whatever but that securities and bullion of very great value should have the best possible protection, irrespective of environment, but there is also the question of dangerous environment *per se*, and this at times can be the most important factor in calculating the strength of a room.

Now, as safemakers with the knowledge and experience we possess, we know how, under a given set of circumstances, our work may be attacked. It is this knowledge which dismays us when we are faced with the unwisdom of a selection in security work which we know to be of inadequate strength to requirements. Too often the decision in these matters is a compromise between price and security and for this reason we are, in many cases, compelled to offer alternatives of a lighter and cheaper quality than we know to be desirable from the point of view of true security.

The potential damaging effect of scientific and mechanical development during ensuing years will be felt more on the strong rooms than on the main building. It is therefore, the more important to erect the best which skill and science can reasonably produce at the moment of building.

In carrying this reasoning to its logical

conclusion, it must be realised that there is no limit to the strength attainable in any installation. Against this fact we know that, given unlimited time and appliances, the strength of anything can be overcome. That is obvious, but any alarm which may be raised by such a statement can be allayed by the knowledge that we are able to define pretty thoroughly the limits of time in which attackers may work. We also know that they are only able to operate under certain conditions. Therefore, in making up our strengths and adding for the margin of safety, we are able to produce security units definitely calculated to be strong enough to resist any feasible form of attack.

Needless to say, in many cases the design resulting from our calculations represents our heaviest work. The additional allowance to give a margin of safety already referred to, is, in some cases, necessarily very high ; the most noteworthy examples of this are the standards of security adopted in the U.S.A., and perhaps, to a lesser degree in Australia.

In the former country it is no exaggeration to say that their biggest installations are some five times heavier than the corresponding work in this country. Obviously the main reason is one of greater risk. One's calculations on risk *must* be on the lines of an increase rather than a decrease in future ; and a high class installation should reasonably be expected to remain modern for a period of perhaps 25 years.

The reasons for an additional allowance of strength beyond what the casual observer would think necessary are best known to us who constantly get reports on attacks, both successful and otherwise, at home and abroad. As experience of life proves that it is often the unexpected event which surprises or dismays us, so in security work provision should be made against an unexpected combination of circumstances which often could not have been definitely foreseen. Such allowances, though hypothetical, are no less necessary.

I will now briefly describe the three patterns of safes which are in the greatest demand for ordinary purposes, and with which many of you will be familiar, after which I will deal with the question of Bank Treasuries in greater detail.

The first public demand is, and I think always will be, for Safes and Cupboards which will preserve their contents against fire. The essentials in a safe of this purpose are that it should be of a sufficiently rigid construction to resist fall and that its walls, of some four inches in thickness, should be packed in such a way that they will resist the action of heat when embedded in glowing embers or hot debris for a considerable period. Apart from the walls it is most important that the door should fit into its surrounding frame in such a way that all ingress of heat from without is effectively shut off. The picture before you shows a section of such a safe as is in common use and which is designed to meet the above-mentioned risks. I might here remind you that in the event of a fire, if the safe has been subjected to great heat, it is always well to leave it for a day or two for the purpose of cooling before opening the door. Contents of safes which have withstood a fire have been destroyed before now by opening the door before the safe is cool when, owing to the inrush of oxygen. the contents are immediately fired. Fire resisting cupboards as distinct from safes are often built of a ferro-concrete construction.

The next class of safe is one that is sold by all makers to combat the risk of fire as well as that of the burglar, and is in general use throughout the country. This design is often founded on that of the fire-resisting safe, but its plates are thicker and armour-plate protects the locks to prevent the action of the drill. As it is not always possible to include the tongue and groove construction for the door, some safes are now fitted with a sliding proofing case on the back of the door, which, on being closed, is pressed into such a position that it makes practically an airtight joint on all its four edges. This is justly regarded as one of the best modern improvements introduced into safe-making. It is very novel, quite simple, fool-proof in action and inexpensive. Certain appliances are fitted to the inside of the door so that if the locks are removed by any means the main bolts are automatically secured in the closed position. These safes are eminently adapted for certain purposes, but just as too much should not be demanded of an automobile of low horse-power, so it is equally important that this class of safe should not be overloaded with contents of a very valuable nature.

We now come to the third class of safe, which, to my mind, is of the greatest interest for the reason that so much is demanded

of it. It is a safe which is built to stand alone unprotected and unguarded for various lengths of time and large numbers of this type have been constructed on the understanding that they can be left, fully loaded, over a week-end. It is built to resist both the use of liquid explosives as well as that of the cutting flame, whether generated by gas or electricity. The illustration before you shows a section of

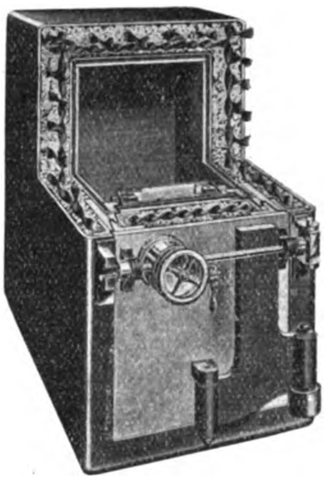


FIG 2.—Crane Hinge Anti Blow Pipe Safe. (Inside out construction.)

one of these A.B.P. (Anti Blowpipe) Safes. The principle on which they are built is that the actual strength of the safe, in which the owner places his confidence, shall be the last thing to be attacked in the event of an effort to break in. The majority of safes in existence are built with the strongest plate outside which on account of its exposed position can be the more easily attacked. We have reversed this design and are now building our heaviest safes with the strongest plates inside, thus the outer plate changes its position and becomes the inner line of defence. The advantages of this design are obvious, for as the attack proceeds, so the difficulties increase, the burglar's area for operation diminishes and his field of vision becomes less. Suppose his intention is to attempt to cut a hole of 4″ diameter through the internal plate, it would be necessary to commence with a hole of at least 12″ diameter externally. In safes of this construction the material used for the inside and strongest slab is a special alloy which offers the greatest known resistance to the action either of drill or cutting flame. For a purpose which I will explain to you later the door is hung on a crane hinge, which is the most effective manner of obtaining an air and watertight fit of the door into its frame. The final movement in closing is to turn the large hand wheel which presses the door bodily inwards causing an hermetical joint to be made.

And now I come to the all-important question of the best way in which Strong Rooms should be constructed. There is some diversity of opinion on this subject, which is perhaps a good sign, but in this question I consider that the theory of the designing board should give way to the results of actual test.

Now in all Strong Room work the greatest interest centres on the door, because provided you have good strong walls which are properly designed, the safemaker has to provide for blocking up the one weak spot in the room, which, of course, is the doorway. Here you have a break in your line of defence, and the skill of the safemaker is shown by the manner in which he can arrange to make this good. With regard to the construction of the walls, the principles followed are similar to those adopted in building heavy doors, and consist in placing as many independent obstacles as possible or different lines of defence against the burglar so that he is unable to persist in one method of attack for any length of time.

Provided sufficient space be available, I consider the best form consists of an outer wall of hard Staffordshire Blue Bricks, which protect an armed concrete wall made up to a certain prescription, and reinforced in a scientific manner with hard steel bars. Inside of this should come a complete steel room of a thickness of from 1½″ to 3″ of tough steel, armourplate or unburnable alloy, according to the requirements of the situation.

The picture before you shows a test wall which has recently been built to prove the efficiency of what I may call scientific reinforcement. The merits of this system are great, as owing to the irregular formation of the steel reinforcement, the burglar, who we will suppose is using the blowpipe flame, is constantly losing touch with the metal he is endeavouring to cut. It is sometimes found impracticable to give up sufficient space to build walls such as I have described, which might easily be 3ft. thick. When this happens we have to compress our

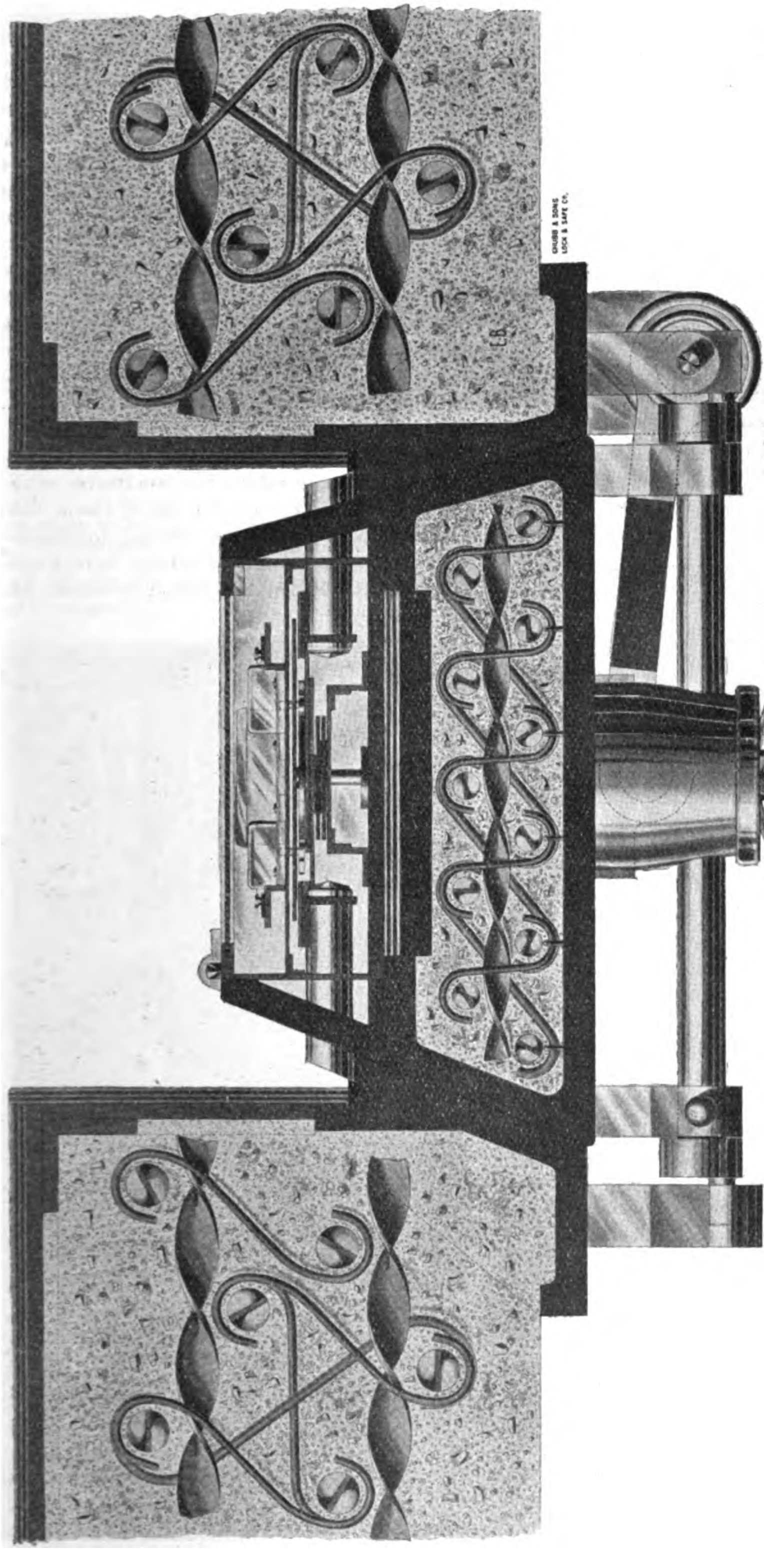


FIG. 3.—Horizontal Cross Section. Chubb Mark VI. Treasury Door (Cast Manganese Steel), clear opening 7 ft. high x 3 ft. wide. Details of the irregular arming of the Strong Room walls are shown either side of the door section.

strength which whilst being a more costly business adds considerably to the inside dimensions of the room.

This compressed strength consists of two independent steel or armourplate walls, the space between being filled up with the special mixture of armed or reinforced concrete. A strong room of this type is known as a triple treasury, and although of less thickness than the former walls described, still offers three lines of defence to be attacked by various means.

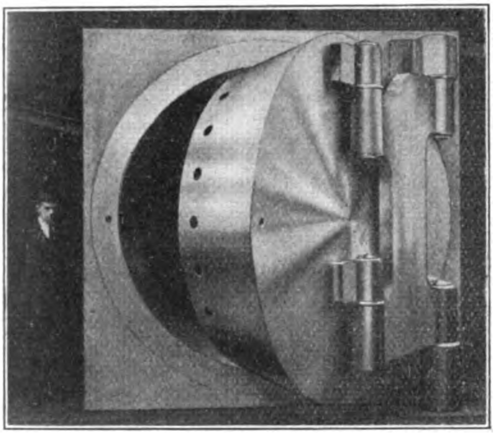


FIG. 4.—Mark VI. Treasury Door (Circular) in course of construction, weight 20 tons.

Doors suitable for the walls I have just described are built either circular or rectangular in shape, and I hope shortly to show you cinema pictures of both of these in course of construction. If time admits, and if anyone is sufficiently interested, I shall be glad later on to compare the relative merits of these two forms of doors. Until this year most good treasury doors have been built by securing together a number of plates of varying degrees of hardness and protecting them from the action of the blowpipe flame by different materials.

Now, the ideal door towards which all thoughtful safe designers are working is not one which allows of the exposure of its component plates on which it relies for its principal strength. In this new design we have departed from all precedent, and although I do not claim that the new type of door is perfect, it represents, so far as I am aware, a great advance on anything that has yet been built in this country. The door itself consists of a hollow cast manganese steel box two inches thick all over and about two feet deep. Externally this is very accurately machined so as to ensure that it makes a metal to metal joint with its surrounding frame, which is cast in one piece out of the same metal. The interior of this box is filled up to a depth of about sixteen inches with the doorplate of armourplate and unburnable alloy, together with its additional flame-resisting covering. In front of the flame protector and directly behind the two-inch slab of manganese steel is placed an electric screen, which gives an alarm on being penetrated by any method. Inside of the doorplate is placed the lock and bolt mechanism. When the smaller wheel on the outside of the door is turned the circular bolts shoot out and are secured behind the frame, which, of course, prevents the door from being pulled open, and the driving mechanism of these bolts is controlled by four keyless combination locks, which can be used either singly or in pairs. I fear there is not time this evening to dilate on the merits of this type of lock, which from every point of view is superior to the key lock on security work of this sort. Instead of a keyhole extending from the outside right to the most vital part of the mechanism, you have a

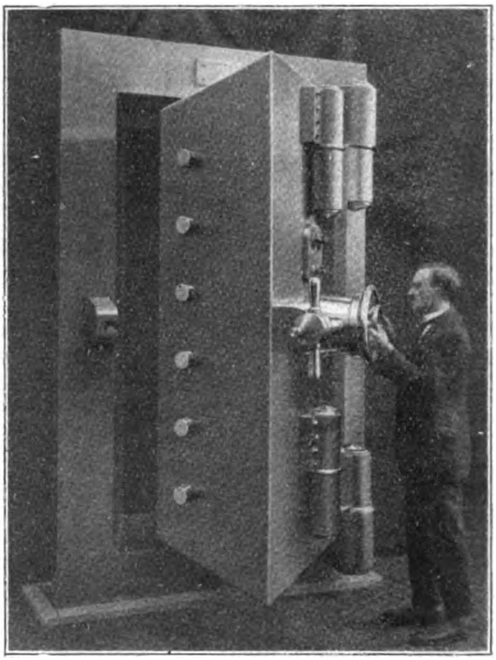


FIG. 5.—Mark VI. Treasury Door (Rectangular); weight 15 tons.

steel spindle or propeller, which is itself fortified to resist the action of drill and flame; it is turned to various diameters

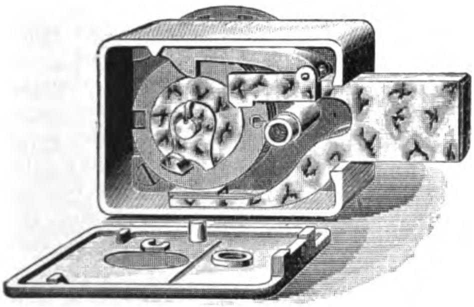


FIG. 6.—Keyless combination lock with back plate removed showing interior. When the back of the lock is replaced in position and the wheels revolved, the back is locked and cannot be opened by an unauthorised person in order to find out the combination in the absence of the owner. It is impossible to remove the back plate again until the wheels are set up to their secret combination.

as it passes through the different layers of material, thus preventing the successful injection of liquid explosives. It is also worthy of note that the locks are not set in a direct line with the spindles, but by an arrangement of gears they assume a position independent of the lines of force which drive them. On the outside of the door is seen a knob attached to a small dial with numbers 1 to 100, and to withdraw the lock bolt, prior to opening the door, all that is necessary is to turn the knob to any four pre-arranged numbers between 1 and 100. The variety of possible combinations runs into several millions, and the numbers can be readily changed by the owner in a few minutes.

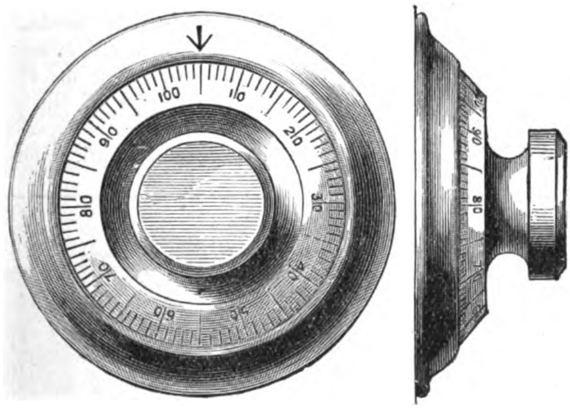


FIG. 7.—Outside Dial of Keyless Combination Lock.

The interior of the locks is one of great simplicity and consists of four wheels placed concentrically on a steel spindle. On the periphery of each wheel is a slot. To open the lock it is necessary to turn these four wheels in such a manner that the four slots are all in line and allow the tail of the bolt to fall into them, which done the bolt may be withdrawn. In order to change the combination a small square key is inserted through the back of the lock and penetrates a small square hole in each of the wheels. On turning this key the centres of the wheels are loosened from the periphery with the result that relationship between the centre or driving part of the wheel to the slot on the outer edge may be altered. Having loosened the centres by turning the square key the operator turns the outside knob to the new numbers on which he wishes the lock to be set, and this effected he turns back the square key on the inside and thus fastens the wheels on the new set of numbers.

An additional control is given by the Time Lock, which you will shortly see

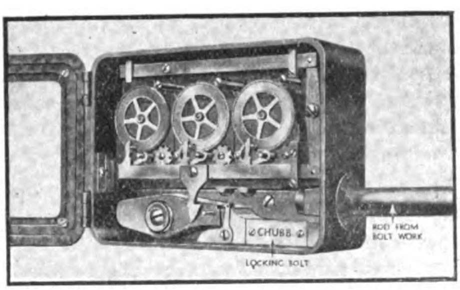


FIG. 8.—A 76-hour Time Lock. (Another type has four clocks and can be wound up 96 hours.)

working. This consists of a bronze case containing four independent high quality chronometer movements. When the door is closed at night the time lock is wound and set in such a way that it will not permit of the door being opened, even by those in possession of the combination, until the pre-arranged hour. This lock was invented as the result of a burglary, when a bank manager disclosed his combination at the point of a revolver, and it is evident that where these locks are used no apprehension need be felt if the combination becomes known or in some cases if keys are stolen.

Considerable surprise has been evinced at the working of the time lock but in reality these locks are extremely simple in action and, at the same time, perfectly reliable. They do not replace keys or combination locks but they are an additional check.

In many quarters the fallacy exists that when the lock goes "off guard" the door will come open, but such is not the case, the truth being that when "off guard" the door may be opened by the holders of the keys or combinations. As stated the lock consists of four independent watch movements in a bronze case, each of which can be wound up to run for a period of 96 hours. At the expiration of the time for which any one movement is wound (and they are generally all wound for the number of hours during which it is required to keep the strong room locked) the small arm on the face of the watch movement comes into operation and causes a lever to fall which, by its altered position, leaves a free passage for a rod from the main boltwork of the door to travel in. As long as this passage is blocked the main bolts cannot be withdrawn but the moment the obstruction is automatically removed the bolts can be operated if they are not held by their locks.

In instances where keys of strong rooms constantly change hands, and where there is a possibility through inadvertence of a duplicate having been made by some unauthorised person, the time lock affords a very great additional security.

The method of swinging this door is one of some interest and you will have observed from the illustrations that the hinge stretches right across from the frame to the centre of the door. This is called a crane hinge, and is so made to ensure a metal to metal fit. By this means the last movement in closing is that of a direct slide inwards when both the back and front edges of the door move parallel to each other. Thus, to shut the door, the first movement is to swing it in the ordinary way until it is within some three inches of being closed; at that point the pressure mechanism, which consists of a bar fitted with an eccentric movement at each end, is engaged and on the large wheel being turned the door is driven bodily home. The steel bolts are next thrown by means of the smaller wheel and the combination lock knobs are given a half turn and the door is locked.

With regard to the general layout of a large treasury, it may be of interest to you to see a plan of what may be called an ideal installation which, owing to the congested state in the city, is, I fear, seldom realised in its entirety in London.

In the centre of the plan you will observe the triple treasury is built. The outer wall of armed concrete allows of sufficient space between it and the triple treasury to meet all the bank's needs, which includes a records room and heavy cupboards for the custody of silver on the one hand, whilst the other side of the chamber is laid out for use as a Safe deposit, adapted to meet all probable requirements.

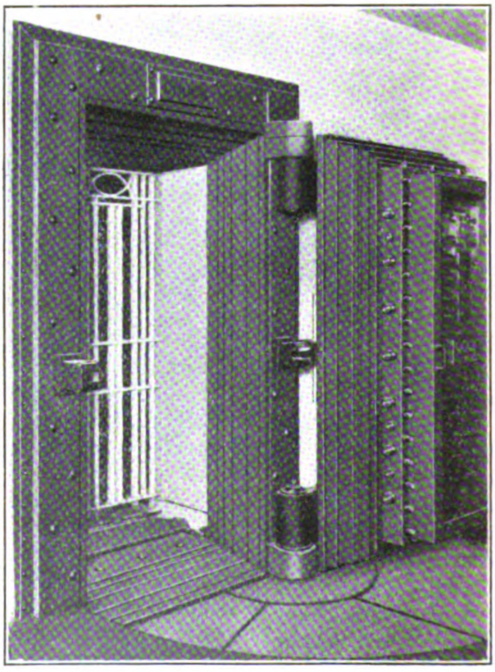


FIG. 9.—Entrance to an Australian Safe Deposit.

In the limited time at my disposal it is impossible to dwell at any length on a number of details which are of considerable interest to the public generally. The question of safe deposits with its kindred subjects of lighting, ventilation and burglar alarms, is one of great interest, and it is only a matter of time before there is a public demand for this form of security in this country. As a point of interest I was informed in San Francisco that with a population of 600,000 there are upwards of 200,000 safe deposit compartments available for letting to the public.

I will now show you a film which will give you some idea of the work necessary in producing doors of a heavy type. Two doors were put in hand simultaneously, but owing to the recent engineering strike the circular door, which, perhaps, offers the most novel features, has not yet been completed. The rectangular door, however, weighing some fifteen tons, and of the new design of which I have spoken will be shown to its completion.

After the film, I shall be pleased to explain to the best of my ability any points on which anyone present would like enlightenment.

[The paper was illustrated with numerous lantern slides and cinematograph views.]

DISCUSSION.

Mrs. White asked whether Messrs. Chubb were the constructors of most of the safe deposits in different parts of London. She also enquired how it was that there were so few double-turn locks in use in England. Double-turn locks were in frequent use all over France. She would also like to know whether there was any museum which specialised in old locks, keys and safes.

The Author, in reply, said Messrs. Chubb had built some safe deposits in England, but they had built more abroad than at home. They had built large numbers in Belgium and in other parts of the world, but only a relatively small number in this country. Double locks, which were locks with a double action, were not very much in use in this country. He thought it was largely a question of national character. The average Englishman thought that the ordinary single action lock was good enough, whereas the foreigner preferred to have the dual movement. There were several museums in which one could see old locks, keys and safes. One very fine antique was the door taken from Newgate, which was now in the London Museum. The South Kensington Museum contained the examples of antique locks with filigree work around them which he had shown in one of his slides. Florence had a number of keys, and the Cluny Museum in Paris had a very fine collection of Renaissance and Gothic locks.

Mr. F. Chatterton said in the film which the author had thrown on the screen he noted that the hinge was being ground in order to detect any defects which might exist in the metal. He would like to know whether X-Rays had been used for determining the same result.

Mr. Chubb said X-Rays might be of use, but the object of grinding, apart from looking for defects, was to produce a smooth and finished surface, so that two things were accomplished with the one operation.

Mr. R. Langton Cole asked if it was not the case that the time lock had lost in favour of recent years, and, if so, what was the reason?

Mr. Chubb said his own experience was that the time lock had not lost ground. It was used just as much at present as before the war. In the last nine years the number in the United States had increased from 22,000 to 30,000. Those were the figures which he had been given last year, and he had been informed that no instance of a lock out, owing to a defective modern time lock, was on record. In America a regular army of men was employed going round the country overhauling the time locks, which were examined at least once in six months. He would say that their use was on the increase rather than on the decrease.

On the motion of the Chairman a hearty vote of thanks was accorded to the author for his interesting paper, and the meeting terminated.

OBITUARY.

Samuel Walker.—Mr. Samuel Walker, who was elected a Member of the Royal Society of Arts in 1888, died at his residence at Sydenham on the 10th December, in his 82nd year. He was in practice as a surveyor up to the time of his death.

He was articled as far back as 1857 to the late Mr. Francis Vigers, and in his early twenties came into prominence as one of the ablest of compensation surveyors of that time. He was engaged, on behalf of the Treasury, at the age of 26, in buying out the interests in the properties covering the site now occupied by the Law Courts. From then up to his death, he was to be found in a very considerable proportion of the larger cases of compulsory purchase relating to property in and around the Metropolitan area. Among his private clients were included some of the great

banks and insurance companies in the City of London.

He was a very early member of the Surveyors' Institution, a member of the committee of the Incorporated Benevolent Society of Auctioneers and a director of the old Auction Mart. He was also a Past-Master of the Plaisterers' Company, and for a number of years was a member of the board of management of the St. Anne's Home at Redhill.

THE CHINESE COTTON INDUSTRY.

The first cotton spinning mill in China was established at Shanghai in 1890. This was followed in 1891 by the Hupeh Textile Mills at Wuchang, and from these two mills, with a spindleage of 65,000 in 1891, the industry has expanded until in December, 1921, there were 73 Chinese and 19 foreign mills, having 2,692,046 spindles. These cotton mills are spread throughout the different Provinces, but Shanghai is the centre of the industry. Of 92 mills having 2,692,046 spindles and 12,191 looms, 37 are in Shanghai.

The following table shows a comparison of the Chinese and foreign cotton mills in operation and projected in Shanghai in January, 1922:

Nationality.	Mills.	Spindles.	Looms.
Chinese:			
In operation	19	499,346	3,090
Projected	4	185,940	1,750
British:			
In operation	5	255,284	2,153
Projected	–	4,000	440
Japanese:			
In operation	13	352,180	1,986
Projected	11	322,956	1,000
Total:			
In operation	37	1,106,810	7,229
Projected	15	512,896	3,190

Some Chinese cotton is of the short-staple variety and of poor quality, so that foreign fibre must be imported for the manufacture of the finer grades of yarn. However, the secretary of the Chinese Maritime Customs states that the cotton used in the mills of China is mostly domestic, and although a few of the foreign mills consume Indian cotton, this kind does not find favour in the Chinese mills. This opinion may change owing to the very low price of Indian cotton as compared with Chinese. China exports as well as imports raw cotton, but exports have dropped steadily from 76,910 long tons (of 2240 lbs.) in 1918 to 63,812 tons in 1919 and 22,381 tons in 1920. The low figure of 1920 resulted from the great shortage in the Chinese cotton crop, larger local consumption, and curtailment of Japanese buying. The stocks on hand were so small that increased imports were necessary to supply local mills. These imports came principally from India, Japan, Hongkong, and the United States, and rose from 11,316 tons in 1918 to 14,223 tons in 1919 and 40,374 tons in 1920.

According to a report by the United States Economist Consul at Shanghai, from which the foregoing particulars are taken, it would appear that no statistics are available to show the actual production of cotton in China, but the average yield per acre is reckoned at 490 pounds of seed cotton or 176.46 pounds of clean cotton, and the customs report for 1919 gives 595,200 to 714,500 tons as the total production. Shipments at the port of origin have increased to a large degree, and there is no doubt but that the production of raw cotton is also increasing. This increased production of cotton, the decreased exportation, and the increased importation indicate that the cotton mills in China are using larger amounts of domestic as well as foreign fibre.

The universal financial stringency and the deflation in the value of all commercial commodities are likely to exert a depressing influence for some time, but the continued expansion in the capacity of existing mills as regards both spindles and looms shows that the cotton industry of China is in a prosperous condition. Important work is being done in connexion with cotton improvement and the areas devoted to its culture are gradually being extended. China probably ranks third in the list of cotton producing countries of the world, and, with cotton piece goods as one of its chief imports, the cotton industry in that country seems assur d.

A NEW INSULATING SLAB.

Ice and Cold Storage, quoting from *Die Kälte Industrie*, describes a novelty in insulation. Amongst the materials used in modern refrigeration technique to prevent the admission of heat the cork slab stands first, because hitherto no other insulating material has been found that impedes the progress of moisture so effectively as the cork slab. It is an artificial product made of small pieces of cork, which are held together surrounded with tar. The complete enclosure or watertight envelope of the individual pieces of cork prevents the passage of water or moisture into the cork material itself, so this possesses an excellent insulating power.

Another material which has also been widely applied as a protection for cold is peat, which is worked up in many ways. Its insulating value is not inferior to that of the cork slab if properly prepared and in quite dry condition. But it has the property of absorbing water and moisture, as it cannot be so completely protected as the cork slab. Its insulating value,

therefore, is generally capricious in that respect, when water can find its way in, or moisture can be deposited, which is always liable to occur in refrigerating plants.

As peat is a home product in Germany and can be won in unlimited quantities, and as, further, the peat slab is very light compared with cork slabs, efforts have not been wanting to make the peat slab waterproof by means of impregnation.

The invention specifically referred to now solves the problem of protecting the peat slab from the introduction of moisture so that the insulating capacity can be made to last. Use is made of the excellent cork composition in a combination with peat so that the heart of the insulating slab, consisting of a peat slab, is enclosed in a film of tar as protection against moisture; and outside that it is enclosed in a cork slab shell. In this it is of importance that the central peat case shall not only be lined with a layer of cork slab, but that a shell of cork slab shall be applied by means of a special process. The insulating slab so made is completely protected against the introduction of water and moisture both in the constituent parts of the outer shell and also in the core, and possesses an advantage compared with the cork slab, of less weight and better insulating value. The insulating value is the greater as a slab consisting of several layers of different materials offers greater resistance to the passage of heat than one of the same material all through. The new slabs are particularly suitable for ship insulation, because of their small weight. In order to economise cork slab material in certain cases so as to reduce the weight, the cork slab shell may be done without, on one surface. Of course, in such cases the slab must be so fitted that the unprotected side or surface is not exposed to the settlement of moisture.

GENERAL NOTE.

Production of Rum in Madeira.—The production of rum from sugar cane in Madeira for the current year has been limited by an official decree to 500,000 litres (132,000 gallons). By this decree production is to be reduced by 100,000 litres (26,000 gallons) each year until 1925, after which it will be limited to 200,000 litres (53,000 gallons) a year. Before restrictions were placed on the rum output it averaged about 1,500,000 litres (396,000 gallons) annually. After 1925, writes the United States Consul at Funchal, rum may be made only in the northern part of the island, where there are no sugar factories, and on account of the lack of transportation facilities sugar cane cannot be sent there from Funchal. Therefore the cane grown in the southern part of the island can be used only in the manufacture of sugar and the distillation of alcohol for the preservation of Madeira wine.

MEETINGS OF THE SOCIETY.

Ordinary Meetings.

Wednesday evenings, at 8 p.m.:—

January 17.—C. A. Klein, "Hygienic Methods in Painting the damp Rubbing-down Process." Thomas Morison Legge C.B.E., M.D., D.P.H., H.M. Medical Inspector of Factories, will preside.

January 24.—Sir William Henry Bragg, K.B.E., M.A., D.Sc., F.R.S., Quain Professor of Physics, University of London, "The New Methods of Crystal Analysis, and their Bearing on Pure and Applied Science." Alan A. Campbell Swinton, F.R.S., late Chairman of the Council, will preside.

January 31.—Thomas H. Fairbrother M.Sc., F.I.C., and Arnold Renshaw, M.D., D.P.H., "The relation between Chemical Constitution and Antiseptic Action in the Coal Tar Dyes."

February 7.—Charles R. Darling, F.Inst.P., A.R.C.Sc.I., "Electrical Resistance Furnaces and their Uses."

February 14.—W. J. Rees, Lecturer on Refractories in the University of Sheffield, "Progress in the Manufacture of Refractories."

February 21.—C. Ainsworth Mitchell, M.A., F.I.C., "Handwriting and its value as Evidence." Sir Richard D. Muir will preside.

February 28.—Professor W. E. S. Turner, D.Sc., Head of Department of Glass Technology, The University, Sheffield, "Heat Resisting Glasses."

March 14.—Sir William Warrender Mackenzie, K.B.E., K.C., President of the Industrial Court, "Industrial Arbitration." Lord Askwith, K.C.B., K.C., D.C.L., Chairman of the Council, will preside.

Indian Section.

Friday afternoons at 4.30 o'clock.

January 19.—The Earl of Ronaldshay, G.C.I.E., late Governor of Bengal, "A Clash of Ideals as a Source of Indian Unrest." The Right Hon. Viscount Peel, G.B.E., Secretary of State for India, will preside.

February 16.—J. T. Marten, I.C.S., M.A., Imperial Census Commissioner in India, "The Indian Census, 1921." Sir Edward A. Gait, K.C.S.I., C.I.E., Member of the India Council, will preside.

March 16.—Lieut.-Col. Sir Leonard Rogers, C.I.E., F.R.S., F.R.C.P., F.R.C.S., Physician and Lecturer, London School of Tropical Medicine, "Recent Advances towards the Solution of the Leprosy Problem."

JUNE 1.—JOHN CAMPBELL, O.B.E., I.C.S. (retired), "The Indian and Burmese Sections of the British Empire Exhibition, 1924."

JUNE 15.—SIR JOHN H. MARSHALL, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture).

DOMINIONS AND COLONIES SECTION.

FEBRUARY 6.—SIR RICHARD A. S. REDMAYNE, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S., "The Base Metal Resources of the British Empire."

MAY 1.—L. GUY RADCLIFFE, M.Sc. (Tech.), F.I.C., "The Essential Oils of the British Empire."

Dates to be hereafter announced:

WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Recent Developments in Surface Combustion."

ARTHUR W. REEVES, M.I.Mech.E., M.Inst. Auto. Eng., "Motor Railway Coaches."

MAURICE DRAKE, "The Development of Mediæval Technique in Stained Glass Windows."

EDWARD PARNELL, "The Resources and Trade of Sarawak."

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

HENRY P. STEVENS, M.A., Ph.D., F.I.C., "The Vulcanisation of Rubber." Three Lectures. February 5, 12, 19.

J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards, "Length Measurement." Three Lectures. March 5, 12, 19.

SAMUEL A. DAVIES, Chemical Department, Messrs. Rowntree & Co., York, "Cocoa and Chocolate." Three Lectures. April 9, 16, 23.

HOWARD LECTURES.

Monday evenings at 8 o'clock.

STANLEY S. COOK, "Recent Improvement in Steam Turbines." Three Lectures. April 30. May 7, 14.

DR. MANN JUVENILE LECTURES.

Wednesday Afternoons, at 3 o'clock.

CHARLES R. DARLING, A.R.C.Sc.I., F.I.C., "The Spectrum, its Colours, Lines and Invisible Parts, and Some of its Industrial Applications." Two Lectures. January 3 and 10, 1923.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, JANUARY 1 .. Transport, Institute of, at the Institution of Electrical Engineers Savoy Place, Victoria Embankment, W.C., 5.30 p.m. Mr. F. Handley-Page, "Air Transport."
Swiney Lectures, at the Imperial College of Science, South Kensington, S.W., 5.30 p.m. Professor T. J. Jehu, "Fossils and What They Teach" (Lecture VII.)
Child Study Society, 96, Buckingham Palace Road, S.W., 5 p.m. Miss M. Drummond, "Children's Drawings."

TUESDAY, JANUARY 2 .. Royal Institution, Albemarle Street, W., 3 p.m. (Juvenile Lecture). Professor H. H. Turner, "Six Steps up the Ladder to the Stars" (Lecture III.)

WEDNESDAY, JANUARY 3 .. Colonial Institute, Hotel Victoria, Northumberland Avenue, W.C., 3 p.m. (Juvenile Lecture). Mr. G. de H. Larpent, "Romance of Rhodesia."

THURSDAY, JANUARY 4 .. Aeronautical Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.30 p.m. Herr Hugo Junker's Metal Aeroplanes."
Royal Institution, Albemarle Street, W., 3 p.m. (Juvenile Lecture). Professor H. H. Turner, "Six Steps up the Ladder to the Stars" (Lecture IV.)
Swiney Lectures, at the Imperial College of Science, South Kensington, S.W., 5.30 p.m. Professor T. J. Jehu, "Fossils and What They Teach" (Lecture VIII.)
British Decorators, Institute of, Painters' Hall, Little Trinity Lane, E.C., 7.30 p.m. Mr. P. A. Wells, "Furniture Designs of the XVIII. Century."
Camera Club, 17, John Street, Adelphi, W.C., 8.15 p.m. Mr. W. L. Wastell "The Evolution of the Lantern Slide."
Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C., 6 p.m. Mr. F. Creedy, "Variable Speed, A.C. Motors without Commutators."
Mechanical Engineers, Instiution of (Midland Branch), University, Edmund Street, Birmingham, 7.30 p.m. Mr. J. Wylie, "The Engineer, the Law, and Lawyers."
Chemical Industry, Society of (British Section), The University, Bristol. Messrs. E. F. Hooper and B. B. Waller, "Mechanical Methods for the Propulsion of Gases."

FRIDAY, JANUARY 5 ... Swiney Lectures, at the Imperial College of Science, South Kensington, S.W., 5.30 p.m. Professor T. J. Jehu, "Fossils and What They Teach" (Lecture IX.)
Mechanical Engineers', Institution of (Yorkshire Branch), Philosophical Hall, Park Row, Leeds, 7.30 p.m.
Chemical Industry, Society of (Manchester Section), at the Textile Institute, 16, St. Mary's Parsonage, Manchester.
Philological Society, University College, Gower Street, W.C., 8 p.m., paper by Rev. Dr. P. Giles.
Geologists Association, University College, Gower Street, W.C., 7.30 p.m. The following Paper will be read:—"Certain Jurassic (Aalenian-Vesulian) Strata of Southern Northamptonshire." By Linsdall Richardson, F.R.S.E., F.G.S. The following Lecture will be delivered:—"The Upper Palæolithic and Neolithic in relation to Early Mediterranean Cultures."

SATURDAY, JANUARY 6 .. Royal Institution, Albemarle Street, W., 3 p.m. (Juvenile Lecture). Professor H. H. Turner, "Six Steps up the Ladder to the Stars" (Lecture V.)

Journal of the Royal Society of Arts.

No. 3,659. VOL. LXXI.

FRIDAY, JANUARY 5, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

NOTICES.

NEXT WEEK

WEDNESDAY, JANUARY 10th, at 3 p.m. (Mann Juvenile Lecture.) CHARLES R. DARLING, F.Inst.P., F.I.C., "The Spectrum, its Colours, Lines and Invisible Parts, and some of its Industrial Applications." (Lecture II.)

The lecture will be illustrated with experiments.

Further particulars of the Society's meetings will be found at the end of this number.

BINDING COVERS FOR JOURNALS.

For the convenience of Fellows wishing to bind their annual volumes of the *Journal*, cloth covers can be supplied, post free, for 2*s*. each, on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.

FOURTH ORDINARY MEETING.

WEDNESDAY, NOVEMBER 29TH, 1922.

ADMIRAL OF THE FLEET SIR HENRY B. JACKSON, G.C.B., K.C.V.O., D.Sc., F.R.S., in the chair.

THE CHAIRMAN, in introducing the lecturer said he was the inventor of a very delicate electrical instrument which he had developed early in the war for the purpose of locating enemy gun positions. He would describe how, by careful research he had been able to apply the instrument in question to peaceful purposes, making it a very accurate instrument for scientific acoustical measurements.

The paper read was :

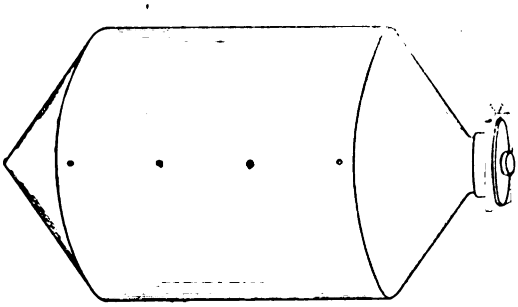
THE HOT WIRE MICROPHONE AND ITS APPLICATIONS TO PROBLEMS OF SOUND.

By MAJOR W. S. TUCKER, R.E., D.Sc., A.M.I.E.E.

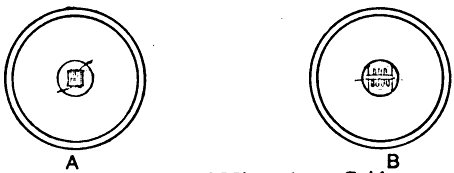
The subject of Acoustics or Sound has recently been brought into prominence on account of its applications to war. These applications have resulted in the formation of a small research organisation supported by the fighting Services and the Department of Scientific and Industrial Research, and in the course of the work of this organisation new facts and developments of general interest have been discovered. Some of these results have been collected together in the paper, and as they are dependent on the use of the Hot Wire Microphone, this instrument has been made the subject of the paper.

The hot wire microphone was essentially a war invention, whose behaviour during the war was imperfectly understood. It has since developed into an instrument not only for detection, but also for measurement of sound and vibratory motion.

It was first designed to detect enemy guns and consisted essentially of a box or chamber, in one wall of which a small opening is made. When the explosive wave arrives at this opening—thereby creating a small excess pressure—a blast of air is projected into the box. In the path of this blast a very fine platinum wire grid is mounted, and by means of an electric current the grid is heated to low incandescence. (Fig. 1.) The effect of the blast is then to cool the wire, lower its electrical resistance and so affect instruments such as galvanometers of suitable type that a clear indication of the blast is demonstrated. The blast produced follows faithfully the pressure variations, and these again are dependent on the nature of the source of the disturbance. Hence the



Gun Microphone (Complete)



Two Types of Microphone Grid
A. Early Type
B. Post Office Type

FIG. 1.—Two Types of Microphone Grid.

record obtained is an indication of the character of an explosion and reveals the fact that heavy explosions consist in the main of very low frequency sounds made up of a highly damped train of waves. The record also reproduces such variations in quality and intensity that they would enable one to identify the source.

A good illustration of the behaviour of the instrument may be given by observing the glowing grid of such a microphone when the sound reaches it. It has been found that the opening and closing of a door with sufficient suddenness gives a very fair imitation of a gun sound. The effect of this operation is to make the grid "blink" momentarily. At the same time a motion of the galvanometer spot across a screen, indicating change in electrical resistance, shows how sensitive this microphone is.

Mere noise, however, does not produce an appreciable effect, as can be shown by sounding a Klaxon horn in the immediate neighbourhood of the microphone.

The selective character of the microphone may further be illustrated by contrasting it with the solid-back carbon microphone. In July of 1916, I was able to take parallel records of sound at Mount Kemmel with these two instruments. (Fig. 2.) There were sounds of all descriptions—traffic, conversation, rustling of wind in trees, and distant gun and rifle fire. The hot wire microphone is shown to ignore all but the low frequency gun-fire.

A number of records may be exhibited showing the properties of the microphone.

Fig. 3 shows the similarity in behaviour of two microphones of the same type when recording the same source (a distant shell burst).

Fig. 4 shows insensitivity of the microphone to a revolver shot at five yards, while giving effects with a gun at 6,000 yards.

Fig. 5 shows a record of a Royal Salute fired on the King's birthday at St. James' Park in 1921 and observed at Biggin Hill 15½ miles away.

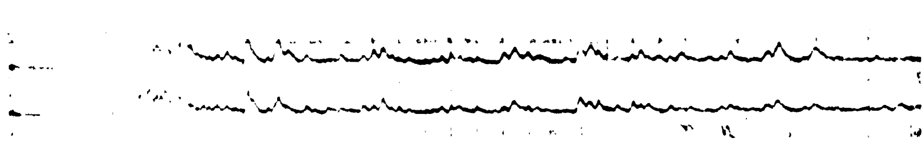


FIG. 2.

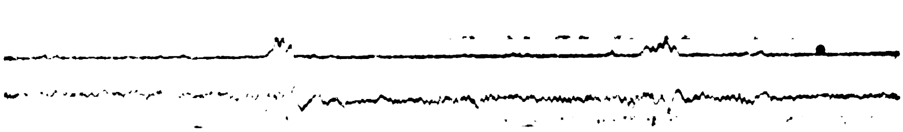
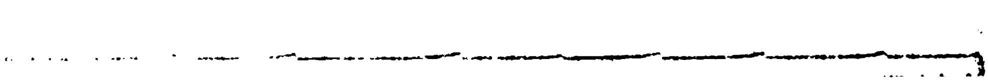


FIG. 3.—Records of two Gun Sounds, with Hot Wire Microphone and with solid back Carbon Microphone.



Record of six revolver shots at a range of 5 yards, followed by gun report at 6000 yards
(Reading from Right to Left)

FIG. 4

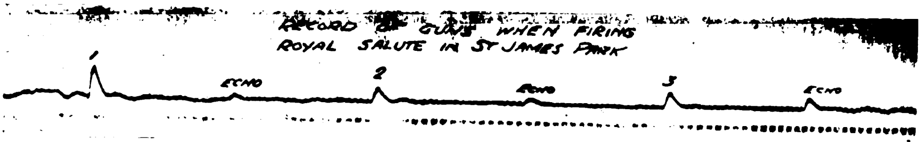


FIG. 5.

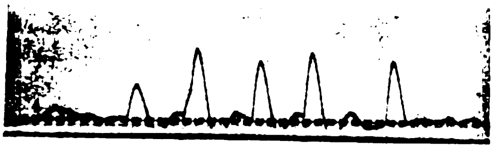


FIG. 6.—Records of "Daily Express" Air Bombs exploded over Hampstead Heath, as heard at Biggin Hill, July 14th, 1921.

Fig. 6 shows a record of rain bombs exploded on Hampstead Heath and observed at the same place, giving a range of 20 miles.

Distinctive records can be obtained from distant claps of thunder, and by means of three microphones sufficiently far apart it is easy to locate the origin of the lightning flash.

All these records have special characteristics by means of whch either can be identified. It must be pointed out, however, that the sensitivity of the microphone depends, not only on the initial temperature and the dimensions of the hot wire, but also on the size of the microphone chamber. For the best reproduction of impulsive sounds, it is of advantage to use a chamber of about a cubic foot capacity and to make small holes or cracks in its walls to eliminate internal resonance.

From the above records it is seen that the microphone has an obvious application to such experiments as that recently conducted in Holland. The Meteorological Department of the Air Ministry asked me to try to obtain records of the great explosion of October 28th, and special arrangements were made for this purpose. Attempts were made to record the effect at Woolwich and Biggin Hill. The results of the observation at Woolwich are shown in Fig. 7, in which three well-marked effects are indicated. The times of arrival of the sound were respectively 19 mins. 39 secs., 19 mins. 45.5 secs. and 22 mins. 42 secs.

The records show, as would be expected, that the sound can arrive by a number of routes so far separated as to give separate concussions. The last effect which is the most prominent was very much delayed,

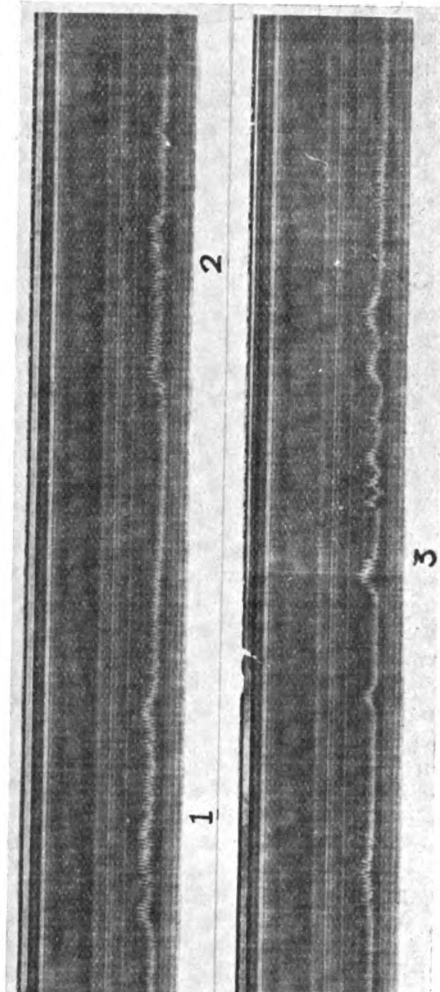


FIG. 7.—Records of the Explosion in Holland, Oct. 25, 1922.

and apparently consists of a higher pitched sound. The results obtained require careful study in conjunction with the known meteorological conditions, but the detail of this work cannot, of course, be described here. It is sufficient to say that from the known values of upper wind, the calculated

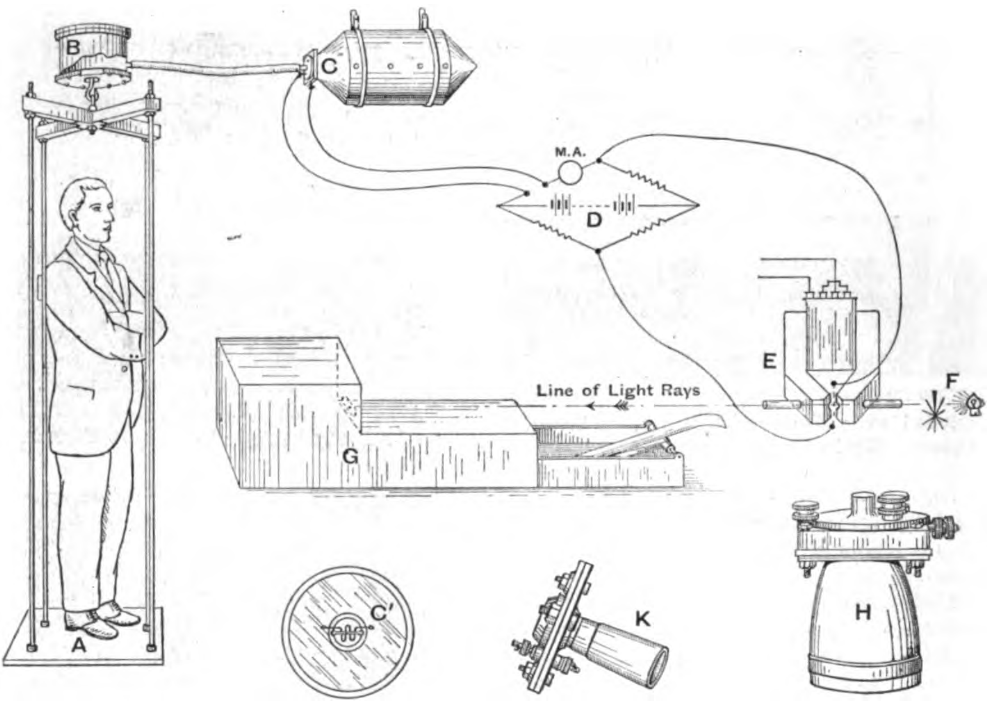


FIG. 8.

time to travel over the range (261.6 miles) is approximately that of the first values quoted.

The records of Biggin Hill are very interesting and appear to give strong evidence of transmission through the ground. It is too early yet to report finally on our conclusions.

Probably the one thing that impresses one most in the above instrument is its surprising sensitivity to low frequency disturbances—disturbances which produce no effect on the human ear, since they are below our range of audition. It is immediately obvious that such an instrument might be harnessed to apparatus for the measurement of vibrations in structures. One such device has been described by Colonel Heald and myself[1] in a recent paper on "Recoil Curves as shown by the Hot Wire Microphone." Vibrations, some vigorous, some imperceptible, are communicated to the human body as the result of the forcible projection of the blood through the arteries due to the pumping action of the heart. Here the shakings of the body are transmitted to a diaphragm whose resultant motion pumps the air from a closed vessel to a microphone by a piece of rubber tubing, and the vibrating air cools the grid in such a manner as to indicate the nature of the body movements (Fig. 8). Associated with the peaks of the recoil records so obtained, we are able (i.) to identify certain movements in the blood, (ii.) to note how these vary with individuals in an apparently healthy state (Fig. 9), (iii.) to show that the peaks are higher during inspiration than expiration, thus indicating a breathing cycle, (iv.) to indicate how they vary when the body is treated with certain drugs, (v.) to observe how they enlarge after exercise (Fig. 10) and (vi.) to show how they may suggest conditions of disease or of mental agitation (Fig. 11). In more recent apparatus the subject, whose recoil is being tested, is placed on a couch, so that he is in a more favourable condition for giving records free from those of the involuntary movements of the body.

This discovery opens up a field of research purely medical or pathological, and to be quite certain of a proper correlation of physiological and physical processes, it is necessary to understand thoroughly the meaning of the physical changes in the hot wire when subject to blasts of air, whether continuous, impulsive or alternating in character. One effect, however, must

[1] Proc. of Royal Society, B. Vol. 93, 1922.

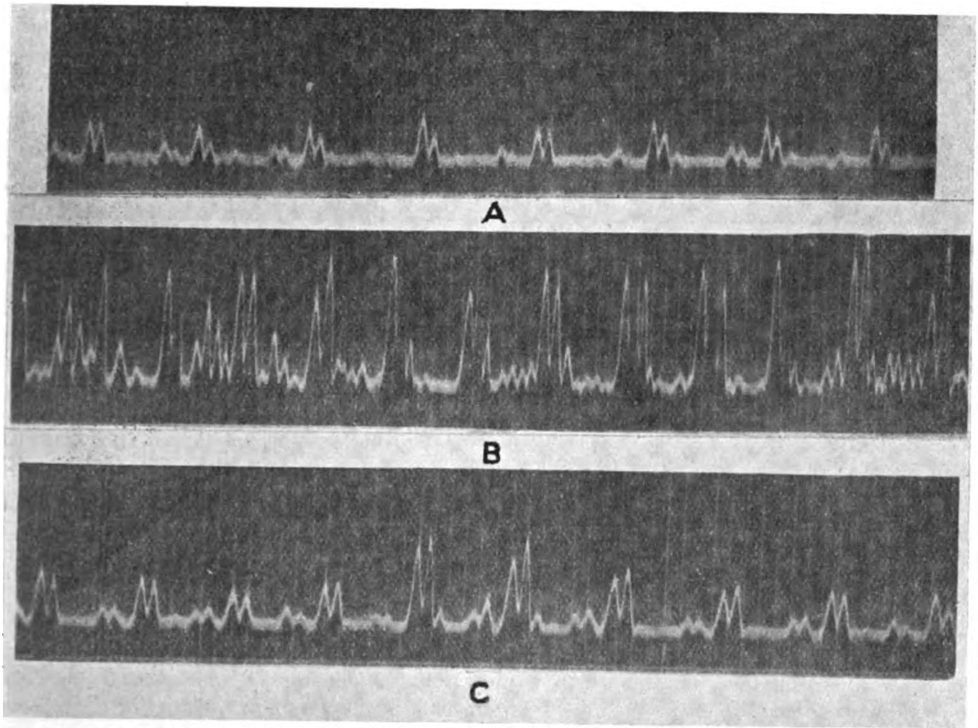
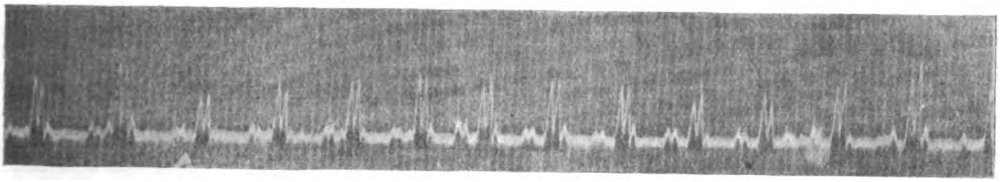
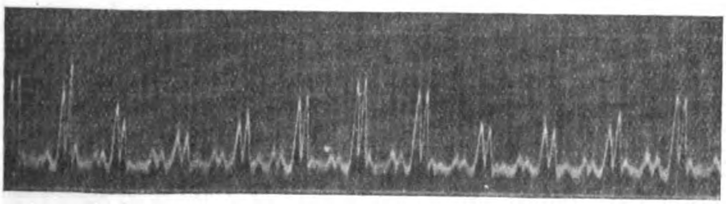


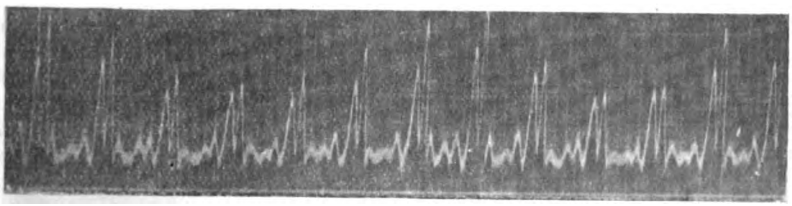
Fig. 9.—Normal Heart Records of Three Subjects taken under the same Conditions on July 8th, 1921.



Normal Heart Record before Exercise.



Immediately after Exercise.



60 Seconds after Exercise.
Fig. 10.

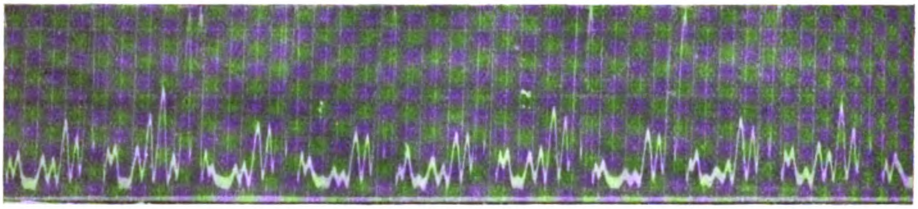
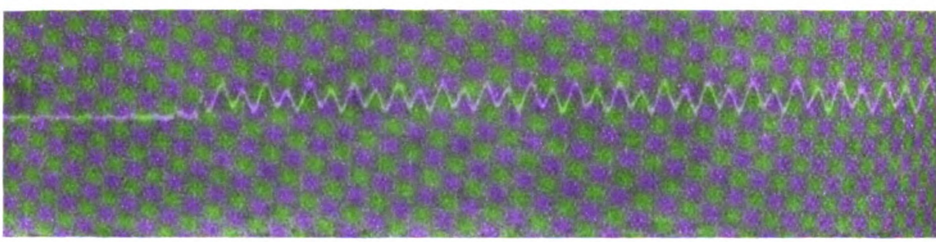


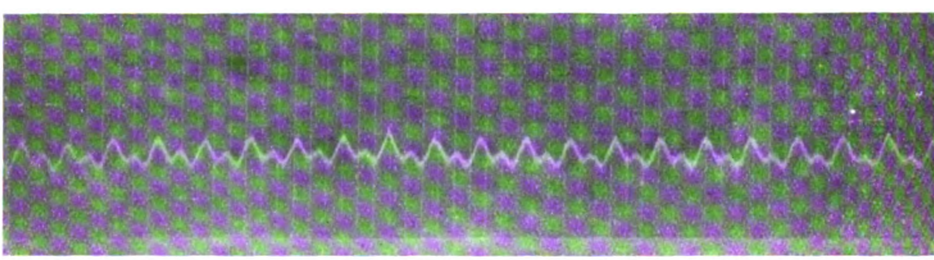
FIG. 11.—Showing Aortic Regurgitation.

be particularly referred to, viz., that the microphone wire is indifferent to the direction of the disturbing blast, since in both cases the wire is cooled, the resistance is diminished, and the record shows a succession of peaks entirely on one side of the zero line.

This statement must, however, be qualified by defining the position of the microphone grid. If the grid is vertical so that the hot convection currents from the wire are perpendicular to the motion of the particles of the vibrating air, the resistance change has twice the periodicity of these vibrations; but if the grid is horizontal, the resistance change tends to be in tune with them (Fig. 12).



(*a*) Grid Vertical.



(*b*) Grid Horizontal.

FIG. 12.—Microphone Records of Air moving in S.H.M.

The microphone as a measurer of impulses, is more difficult to explain than when used for the measurement of continuous sound. It was at first thought that the hot wire microphone could not be used for this purpose, but the remarkable magnifying powers produced by resonance enable us to get sufficient disturbance with sounds of one predominating frequency to affect the hot wire.

In the above statement it was shown that for accurate recording, resonance should be discouraged in the containing vessel by perforating its walls. If, however, these walls were left intact, it was found that the vessel with its microphone orifice had a very definite note of its own to which it would respond with great vigour. Excited by the sound of the same musical pitch, the resonator, as we may now call it, produces intense vibration in the neighbourhood of the hot wire thus cooling it, and moreover, cooling it periodically. This resonator is no new discovery. It was described by Helmholtz, and its theory has received a complete treatment by the late Lord Rayleigh.[3] From known dimensions of the resonator, its magnifying power can be calculated, and it can be shown that

[3] Rayleigh's Theory of Sound. Vol. 2. Chap. XVI.

resonance in a given case is confined to a very short range of frequencies, comprising about six per cent. of the mean frequency, so that it is only capable of responding to a range of about one musical tone.

The overtones to which it can respond are of high pitch, and are relatively feeble, thus making it the most selective type of resonator known.

An approximate treatment of the theory of the instrument is given in a recent paper before the Royal Society,[3] in which the

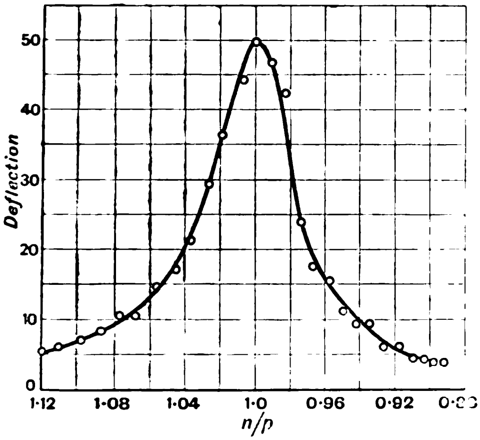


FIG. 13.

resonance curve of Fig. 13 is given. This has been obtained by subjecting the microphone to the sound of a siren whose pitch is gradually raised, and measuring the effect produced. This selectiveness of the microphone can also be demonstrated by a simple experiment.

It has already been stated that the resistance of the hot wire is not only diminished by the vibrations in the neck of the microphone, but that resistance is also subject to variations of a periodic character. If the variations of electric current resulting from such periodic change be magnified by the wireless amplifier, the resulting current is sufficiently large to affect a telephone. If, then, we hum up the scale in the neighbourhood of the microphone, the response to a given note is rendered audible, and by means of a loud speaking telephone, can be demonstrated to a large audience.

The microphone may be tuned by altering the volume of the resonator or by altering the dimensions of its neck—thus a larger volume or a longer neck would be employed for a lower note. In general, alteration of volume is the most satisfactory way of tuning. For the sake of illustration a microphone tuned to 512 vibrations per second, has one quarter the volume of one tuned to 256 vibrations per second, if the necks are equal.

One of the advantages of this type of microphone is its insensitivity to other disturbing noises, as can be shown by substituting a galvanometer for the telephone so that the response of the microphone is shown visually. Here the magnified alternating current is first made unidirectional by means of a crystal rectifier. A Klaxon horn and other disturbances near produce no effect, but the slightest hum on the appropriate note is immediately detected.

Even tapping the microphone produces no appreciable effect, and the power to ignore shock makes it very useful for listening in places where the supports are subject to all kinds of accidental vibration. A carbon microphone, for instance, detects the slightest disturbance in its vicinity, and this is easily shown by tapping it and observing the effect on a vibration galvanometer. For this reason, also, the hot wire microphone can be carried about a room, and will show by the galvanometer deflections the variation of intensity of sound at different points in the room.

Even in this form, the microphone has not shown its maximum sensitivity. It can be demonstrated that if the microphone be mounted with its neck penetrating the wall of a cubical box, whose side contains a sliding door, a much better effect is obtained if the door be opened to a certain degree. The box itself becomes a resonator, and when tuned to the microphone note, the combination is extremely sensitive to a sound of the correct pitch.

This phenomenon of double resonance in which the sound waves surge through the orifice between the two boxes has its analogy with the tuned wireless circuits in a wireless receiving installation. The combination exhibits not one, but two resonance peaks and gives a much wider range of tuning, while at the same time giving large magnification.

A resonator of this type is shown in Fig. 14, and the best effect is produced by such careful tuning that two resonance peaks of equal magnitude are obtained (Fig. 15). So far this instrument is the most sensitive

[3] Tucker and Paris-Phil. Trans. Section A, Vol. 221, pp. 389-430.

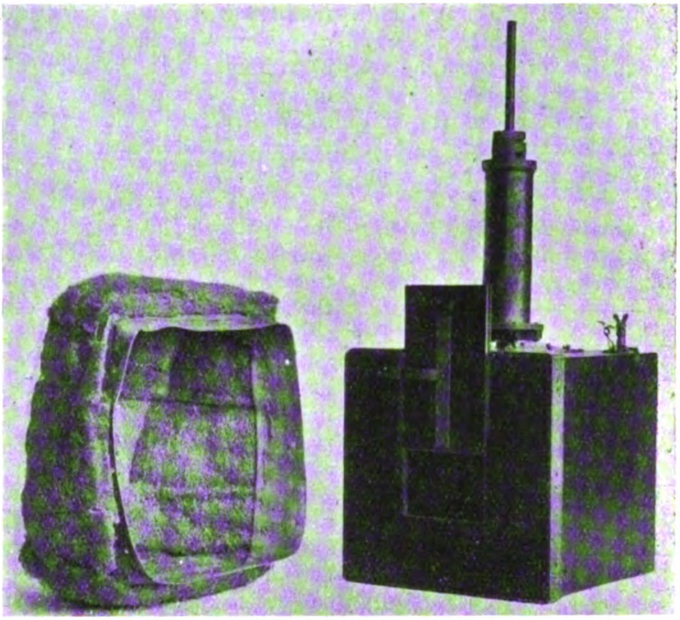


FIG. 14.

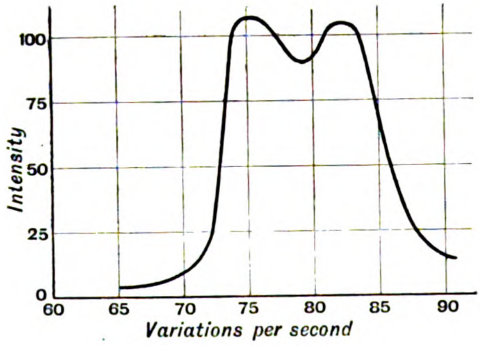


FIG. 15.

detector of sounds we have been able to produce and can easily pick up inaudible sounds within its range. Its high selectivity also enables it to hear in the midst of disturbing sounds.

The greatest trouble that all microphones experience is disturbance due to wind. The hot wire microphone is specially susceptible, and much attention has been given to the solution of this difficulty. We are, however, greatly indebted to Mr. E. S. Player for the discovery of a very efficient wind screening device. This consists of the ordinary "loofah," the effect of whose fibrous structure is to break up any wind impulses without obstructing the passage of air or of sound. The microphone of Fig. 14 is protected with such a loofah screen which is here shown detached from the box front.

We may now turn to some investigations to which the microphone has been satisfactorily applied. Its consistency of behaviour enables it to be employed for the accurate comparison of sounds of the same quality, for it has been shown in the paper last referred to, that the ohmic change produced in the hot wire of the microphone is a direct measure of the intensity of the sound.

If the sounds to be compared are relatively feeble, a well tuned microphone would be employed, but if the sound is very intense, as in the neighbourhood of the Trinity House sirens, a microphone whose note is well below that of the siren is adopted. Thus, two fog horns were compared on the Channel Islands with a microphone of pitch 50 vibrations per second, that of the horns being 180 vibrations per second in each case.

If we use a source of sound of a given pitch, we can find out

(1) How the transmission of such sound is affected by weather conditions.

(2) How the sound is distributed in certain enclosures, such as rooms of different sizes and shapes, and how that sound is modified by opening windows or doors or distribution of the audience, or the furniture in a room.

(3) How the sound is modified, magnified or distributed by the intervention in its path of trumpets, reflectors or obstacles.

Dealing with the first class of experiment, we obtain data of considerable importance to meteorologists. The study of meteorological acoustics was developed at our station at Kingsgate, near the North Foreland, and this station was admirably situated for working on the sirens of different light vessels, whose positions are indicated on the map (Fig. 16).

as heard at Kingsgate—seven miles away. The instrumental effects were checked by ear, but it was only by the instruments that such large variations could be appreciated.

Fig 18 shows a record of the Tongue Light Vessel (three blasts of the same pitch) at a range of nine miles and Fig. 19 shows a record of the Kentish Knock Light

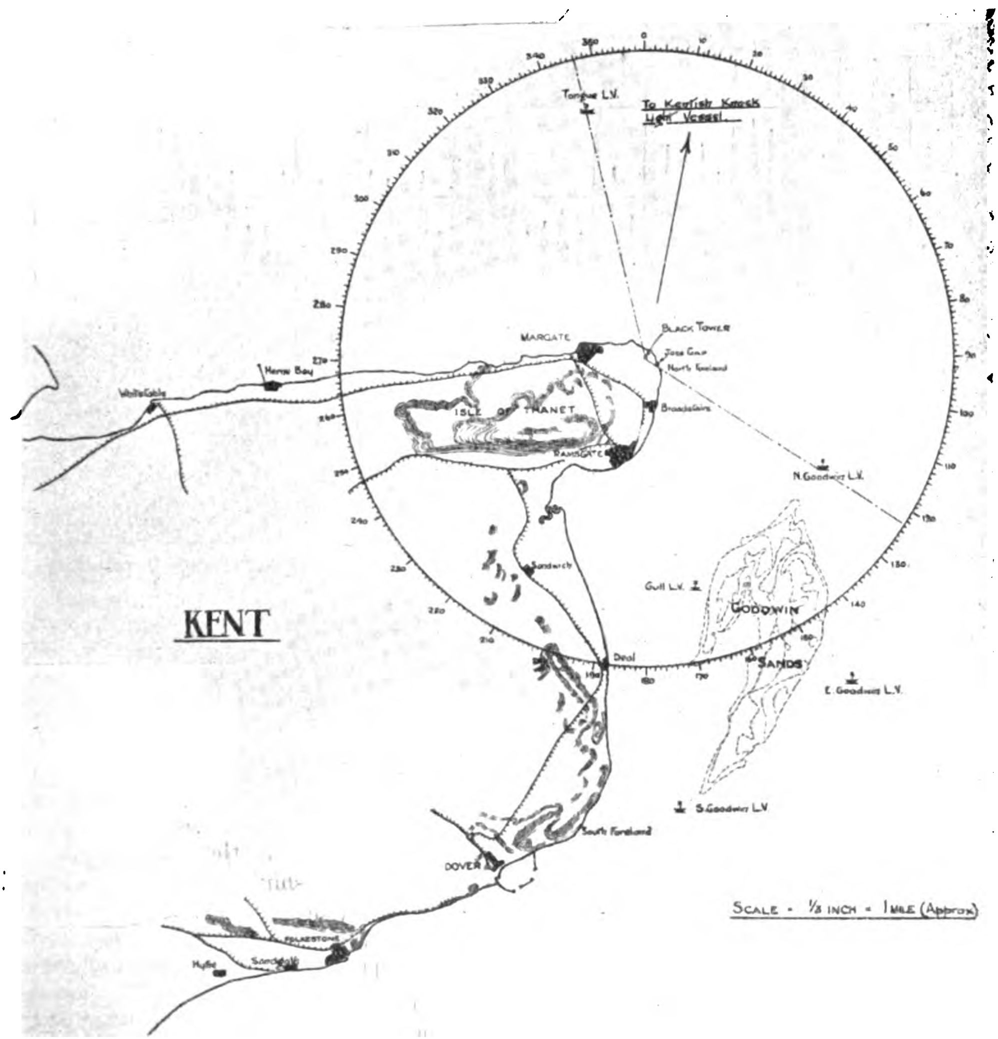


Fig. 16.

Fig. 17 shows how remarkably the intensity of the received sound varies on a typical English summer day when the sky may be clear or flecked with white cumulus cloud. The heights of successive peaks correspond to sounds emitted at minute intervals by the North Goodwin Light Vessel Siren

Vessel Siren—one blast—at a range of 19 miles, the sound taking 1½ minutes to arrive. This sound was quite inaudible, and here all sea and local noises were tuned out—thus illustrating the advantage of microphone reception over aural reception in this case.

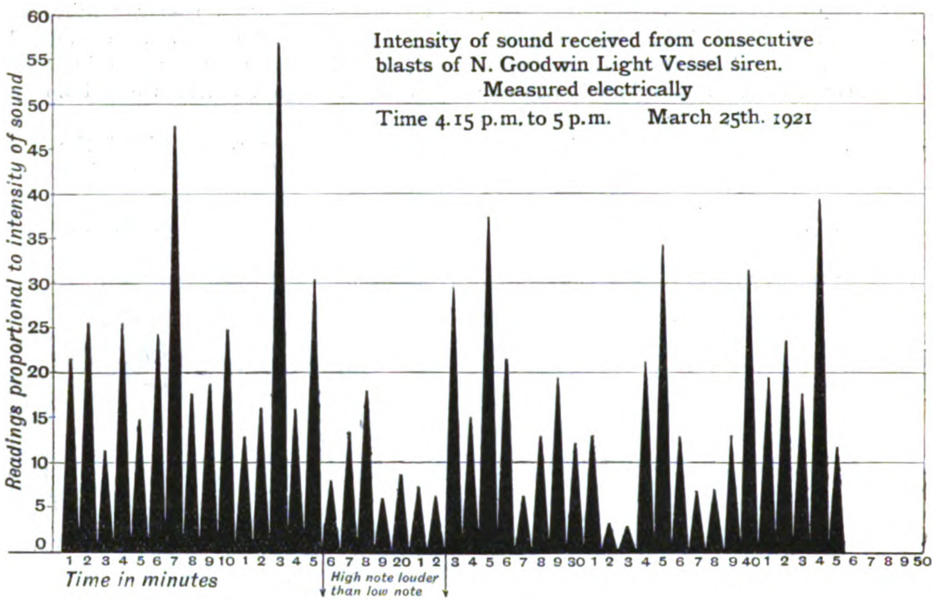


FIG. 17.

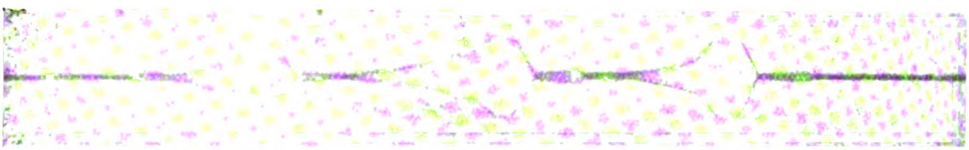


FIG. 18.—Record of the Tongue "Light Vessel Siren," 3 Blasts, Range 9 miles.

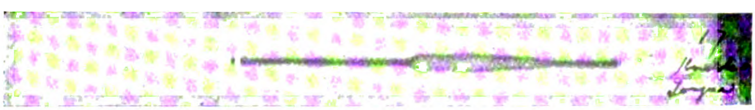


FIG. 19.

In all the above cases, doubly resonated microphones were employed, and through the courtesy of the Elder Brethren, a long series of observations were obtained, extending over a period of several months. For this work the North Goodwin Siren provided special blasts—for periods of 15 minutes—on four days in each week. We were thus able to record sound under all kinds of weather conditions and to obtain from the data thus supplied certain laws governing the conditions of audibility as affected by weather.

Toward the end of May of the present year the Elder Brethren afforded me the opportunity of working with the sirens on the Channel Islands, and I was able to take records on the Trinity yacht "Patricia," while cruising in the neighbourhood of the Casquet Rocks. With the microphone of Fig. 14, records were taken of the new Diaphone Horn which has recently been installed on the Casquets to replace the standard pattern siren During the test, the effects of different conditions aboard were observed by taking records between the siren blasts. The vibration and ship's noises generally did not produce any serious effect. Fig. 20 shows the blast records as observed at a range of two miles. The abruptness of the in-coming sound—a valuable property of the diaphone—is clearly demonstrated, and contrasted with the siren. No attempt was made to reduce the sensitivity of the microphone. At a distance of $4\frac{1}{2}$ miles the sound was still too intense to obtain the whole of the record on the sensitised paper strip using full sensitivity. The time at our disposal prevented our working on

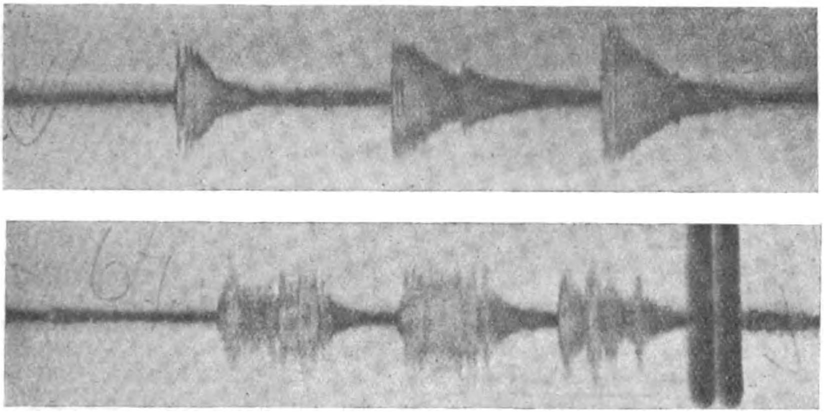


FIG. 20.—C. Diaphone and Siren Records Compared. Range 2 miles.

extreme ranges, but it is believed that a range of at least 20 miles would have been recorded by the microphone. The superiority of the diaphone was clearly demonstrated when the two horns were compared.

A visit to Alderney enabled us to compare the diaphone of the Casquets Station with the powerful siren there installed. Observations taken at close range with the untuned microphone enabled us to decide in favour of the diaphone for all-round listening, although the nature of the distribution of sound round these two sources rendered comparison rather difficult. In two directions the Alderney siren was stronger than the diaphone.

Reverting to our work at Kingsgate, peculiar effects were recorded in fog. A record was obtained of the blasts of a ship's siren, while that vessel was passing through a bank of fog on January 22nd, 1922. The record showed evidence of reflection of a very local character, as it was seen that after a few blasts, the steamer passed out of this region. Another steamer in the neighbourhood gave no such indication, and the North Goodwin siren—slightly to the south—gave a sound perfectly free from echo.

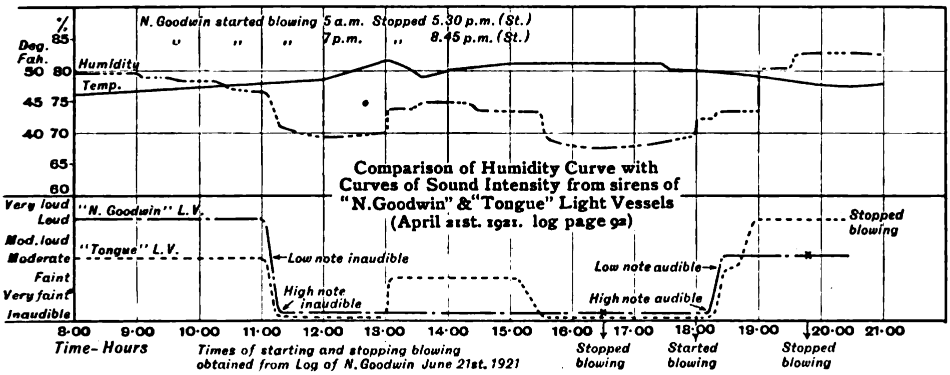
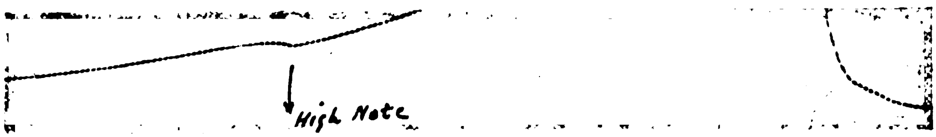


FIG. 21.

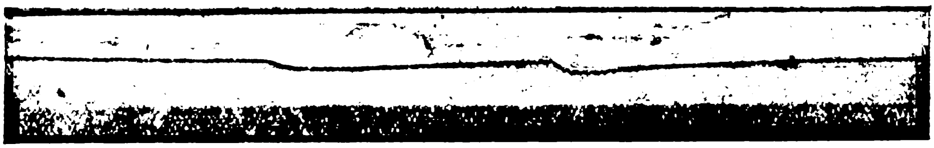
Fig. 21 shows the effect of a shifting fog on the audibility of the North Goodwin siren, and its intimate relation to changes of humidity. It is seen here that at points where the humidity undergoes sudden diminution there is corresponding diminution in the sound of the North Goodwin siren. Variation in humidity means variation in fog-density and during the interval of silence, shown in the diagram, there was a fog bank lying between the source and the ear, but never completely enveloping both. A uniform fog is even more satisfactory for sound transmission than average clear weather. It is the variation in fog density which is so fatal to good listening. This evidence is in keeping with the late Professor Tyndall's observations at the South Foreland.[4]

It is generally accepted that sound is

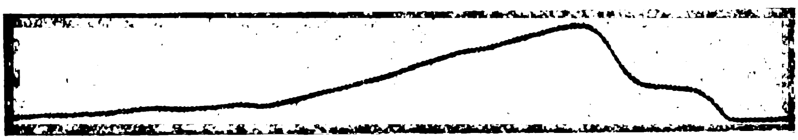
4. Tyndall's Sound. Lecture VII.



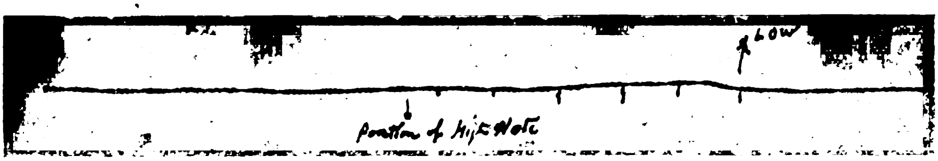
Wind N.N.W. 11 M.P.H.



Wind S.E. 3 M.P.H.



Wind E. 20 M.P.H.

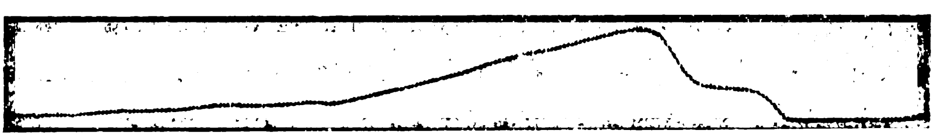


Wind S. to S.S.W. 13½ M.P.H.

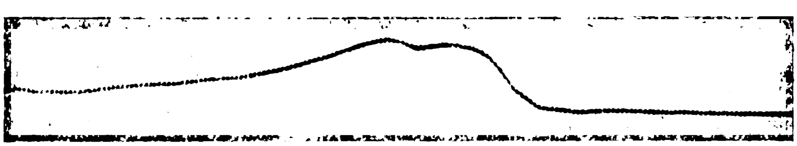
FIG. 22.—Variation of received Sound with Wind (Sound approaching from S.E.).

heard most favourably in a following wind. Fig. 22 shows, however, that this rule is frequently broken, and has directed our attention to a fuller study of upper wind and temperature conditions. If a following wind has a velocity which increases as we ascend it is favourable for sound. The same condition obtains with an adverse wind which diminishes in strength as we ascend. The cases illustrated in Fig. 22 are examples of these two cases.

Fig. 23 is of interest as it shows a record of sound arriving by two distinct paths. The day was clear and there was a strong following wind, whose velocity alternately increased and decreased as the height was



Wind E. 20 M.&.H.



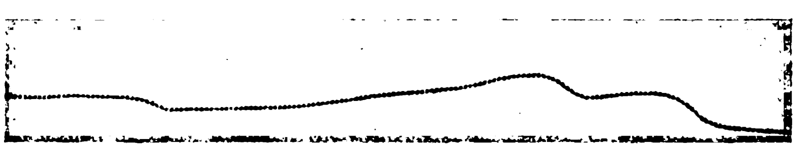


FIG. 23.

increased. The effect is the same as if every blast emitted by the siren were doubled, as heard by the observer.

Other records can be produced showing under what conditions the sound comes in abruptly and goes out abruptly. When observed at a distance a favourable wind is productive of a sharp cut in of the sound.

Under heading (2) the distribution of sound in rooms is a matter of great importance in architectural acoustics, and much interest has recently been aroused because of the failure of certain public buildings to satisfy acoustical requirements. Acoustical properties can be studied if notes of a definite pitch are selected, and duration of resonance can also be indicated by photographic records, and such records would enable us to make measurements. By means of microphone, amplifier and vibration galvanometer, the distribution of sound can be exhibited to the audience, and also the manner in which the distribution of sound is affected by the movements of any person or article of furniture in the neighbourhood of the point at which measurements can be taken. The effects of sounding boards can also be demonstrated.

Under heading (3), it is obvious that from what has been said, the directional effects produced by the intervention of trumpets, mirrors and certain obstacles can be determined. Thus effects may be observed by placing the microphone in the neck of a trumpet and altering its direction relative to that of the incoming signal, or by placing the microphone in the

Polar diagrams
for different sound collectors

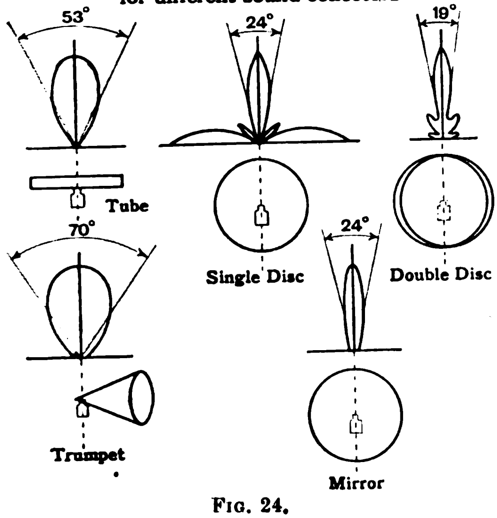


FIG. 24.

focus of a concave mirror and rotating the latter. These effects are indicated by Fig. 24 showing polar curves obtained in actual experiments.

The figure (24) includes curves of :—

(1) intensity at the centre of an open pipe of length equal to the wave-length of the sound used.

(2) intensity at the centre of a single disc when the disc is rotated relative to the source.

(3) intensity between two discs separated by a distance equal to 1/20 of their diameter.

(4) intensity in the neck of a trumpet when rotated.

(5) intensity at the focus of a concave sound mirror.

The radii vectores of the curves shown above their appropriate collectors measure intensities when the collector rotates through 180°.

Before concluding, it may be stated that the above relative measurements are to be regarded as merely a step in the acquiring of absolute measurements of the sound received. Without going into detail, it may be stated that we hope in the near future to be able to measure sounds of a given pitch in absolute units of energy independent of that pitch, and to say what are the maximum ranges of audibility in terms of the average human ear. It is most important that as an out come of this class of work, a unit of sound should be adopted which should be of value for commercial as well as for scientific purposes—something to take the place of candle power, in estimating sources of light.

The hot wire microphone has one distinct limitation—it is relatively insensitive to high pitch sounds—but with the development of more sensitive apparatus for the measurement of effects it will ultimately be available for this class of work also. Intensity of sound, as distinguished by the ear, will correspond to certain ohmic changes, which will be smaller and smaller as the pitch rises—but such ohmic changes, with the sensitive apparatus now at our disposal, should be easily measurable.

In conclusion, it may be said that we have regarded the hot wire microphone as a tool, the chief interest of which lies in the fresh lines of acoustical research which it can open up, and of the more quantitative results which it can obtain. Its function is first to tune out unwanted

sounds, and to concentrate on sound of a definite pitch. It fulfils the same purpose as the tuned wireless circuit, which has been so fruitful in overcoming jamming, and rendering further development of wireless possible. Conflicting noises similarly jam one another, and long distance listening for sounds of a given pitch can only be possible when a tuned acoustical receiver is employed.

The work above described was carried out under the auspices of the Munitions Inventions Department, and the Signals Experimental Establishment. The author is greatly indebted to Capt. Paris and the staff of the Acoustical Research Section for their co-operation in this work.

DISCUSSION.

THE CHAIRMAN thought it might be taken for granted that everyone present had appreciated the very interesting lecture which the author had delivered, not only for its intrinsic interest but on account of the wonderfully convincing experiments with which it had been accompanied. Before the war, acoustics was the most neglected of all the physical sciences and there were very few eminent physicists who made it their speciality. The few who did were well-known, and during the war there was a great demand for their books; new copies were unobtainable and second-hand copies fetched very large prices, as soon as it became obvious that the science was useful in war.

He had had the privilege of seeing some of the lecturer's early experiments, and of following their development until quite recently. Being interested in wireless telegraphy, he naturally thought at one time that the amplifier might be of great use. At one time, indeed, it was thought that it would solve all the problems in acoustics and telephony. It was thought it would save the situation with regard to the hot wire microphone and be essential for it in practical work. Such had not proved to be the case. The resonator which had been demonstrated that evening had practically replaced the amplifier, which had gone into the background and was only used for listening and experimental purposes. That had been achieved because of the very great simplicity of the resonator, which was easier to work, more portable, gave less trouble and made for more accurate work where quantitative measurements were concerned. Personally, he felt almost sad to see the disappearance of the amplifier, but, as had been shown that evening, it was no longer necessary.

He thought Major Tucker had succeeded in clearing up a good many puzzling problems and phenomena that sailors experienced in fogs. What he had said about sirens was very valuable and he had shown what the echo noises really were. He thought that when once the lecturer's work was known to sailors, in the course of time officers on the bridge would be rather chary of abusing the lookout man, in perhaps rather unparliamentary language, for reporting the presence of a siren in an unexpected direction. If the sailor himself had read the paper, he might be in a position to reply to any such accusations. He hoped the facts which the lecturer had brought forward would become known to all sailors, because he had dealt with things which all sailors experienced, but which up to now they had not known how to interpret. Seamen would have good reason to be grateful to the lecturer for his work, and when the results of his experiments had been turned to practical account in light vessels and so on, not only sailors but humanity in general, would be grateful, and in addition the whole medical world and all with whom medical men had to deal. He thought the lecturer's investigations into heart vibrations and the acoustic properties of buildings when carried to their ultimate conclusion would prove of great benefit to humanity. Major Tucker had invented a tool and had shown the best way to use it. It was not everyone who could do that; it was not everyone who saw the results of his invention come to fruition in so short a time as had been the case with this invention.

MR. ALAN A. CAMPBELL SWINTON, F.R.S., wished to congratulate the lecturer upon having produced the very notable and beautiful instrument which he had described, and also on the very successful way in which he had demonstrated it that evening.

He would like to ask whether the word "microphone" was the best that could be found to designate the beautiful instrument the lecturer had invented. Until recently, at any rate, the instrument which was known as a microphone had been one used for the purpose of magnifying minute sounds and enabling one to hear them. It seemed to him that though the lecturer's instrument could be used for such a purpose, its chief utility seemed to be in making minute sounds visible or for recording them. He thought perhaps some such word as "Microphonoscope" or "Microphonograph" would be more applicable, because the chief object of the instrument in question was to detect sounds, not by means of the ear but by means of the eye or by means of a curve of some description. It seemed to him that there were endless possibilities before the lecturer's instrument, but he would not venture to suggest any because he had not had time to consider the matter sufficiently; he thought, however it was obvious that there must be many uses for it, and that the meeting was very much indebted to the lecturer for the exhibition he had given.

Lieut.-Col. A. Cusins said that for the past three years he had been officially responsible for the lecturer, but he had not been responsible for his work. He thought everyone would agree that the lecturer's instrument was a most remarkable one, and realised in a wonderful way the saying with regard to "beating swords into ploughshares." There was one point in the paper on which he would like to enlarge. He thought the application of the lecturer's instrument to mechanical research would be, if not the largest, at all events one of the most important of its developments. The examination of minute vibrations or variations in torque in engines and electrical apparatus would be found, he thought, of the greatest value and importance.

Colonel C. B. Heald, C.B.E., M.D., wished to associate himself with other speakers in thanking the lecturer, with whom it had been his extreme pleasure to work during the past three years. It might be of interest to the Meeting to learn the origin of the heart work to which Major Tucker had alluded. In 1916, he was detailed to conduct the medical examination of war pilots, and it was desired to weigh them accurately. When weighing them on a weighing machine, the only one obtainable at that time, it was noticed that the hand moved. He had tried to record that movement but had utterly failed. A year passed by and then a fortunate chance brought him into contact with the lecturer, and he found that in the same year and at practically the same time, Major Tucker, quite independently, had been recording movements of the heart with a hot wire microphone. They joined forces, and with what he regarded as the best part of scientific work of the kind in question—real team work—they produced the work which had been described, the great majority of it, and all the physical part, being due to the lecturer.

Many people might ask what was the use of taking heart records of the kind in question when one could listen to them with a stethoscope? The answer was that it provided a permanent record free from medical bias. One could not get away from the fact that the displacements of the body, due to the energy of the heart expelling blood from it, as registered by the instrument, were taking place, and it was possible to repeat and compare those records over various intervals of time and transmit them from one medical officer to another all over the world. In measuring the physical efficiency of individuals, it should be possible for their records to go with them if they changed their domicile, and those records should be free from the opinion of this or that Doctor. Such records were extremely useful for showing fatigue, and he had obtained some most amusing records of the effect of alcohol on the action of the heart. Those who doubted whether alcohol had any effect would be entirely convinced if they saw the records of one or two individuals shortly after they admitted having lunched extremely well. Really heavy smoking undoubtedly affected the records, and the effect of smoking two or three cigarettes straight off could be demonstrated. The instrument was also useful in connection with industrial efficiency and the fatigue of various occupations. No work in that direction had yet been attempted, but it was a line for future investigation.

He might mention one interesting record which he had taken. He was taking his Secretary to get a test record, and it occurred to him to try the psychological effect of a rather sudden shock. He was thinking of the possibility of its application by the police; if one could, as was now possible, take records without the individual concerned being aware of it, it might be valuable to the police. He therefore said to his Secretary: "Have you heard they are going to dismiss you?" There was immediately a complete change in the output of the record. Everyone knew that the effect of a sudden shock was to make one's heart stop suddenly and then go on again and he could imagine it being applied to a criminal, who did not know a record was being taken, when suddenly someone said: "Were you at such and such a place?" He would wonder whether to say yes, or no, and his heart would give a sudden flick which would be faithfully recorded in the next room.

The previous day he had taken a record to show the effect of strain. A certain pilot recently carried out a most strenuous flight under very exhausting conditions, and he thought, in listening to his heart, that there was some irregularity; he therefore decided to take a long record, and found that one in every 100 to 150 beats was a complete miss. The lecturer had not referred to the possibilities of a continuous record, but they were many. The record in question was taken for a quarter of an hour, and that was a very important point.

The other possible applications of the instrument to problems in which he was interested were many. It suggested itself for the early diagnosis of that dread scourge, phthisis. It was well-known that the efficiency and movement of the lungs was impeded in the early stages of phthisis, and that could be recorded.

Another interesting experiment in which he and the lecturer proposed to collaborate, was in the damping of the noise and vibration experienced when travelling inside the cabin of a commercial aeroplane. If he did not wear something in his ears, or wireless apparatus when travelling, he was quite incapable of any effective work for hours after landing, the drumming in his head was so intense.

Mr. C. R. Darling, F.Inst.P., F.I.C., congratulated the lecturer on the success of his experiments. Many directions in which

the hot wire microphone was and could be used had been given, but he thought the most important of them all was the one which had met with the least notice that evening, namely, the promise it gave of providing a real unit of sound. One of the main causes of our lack of knowledge in acoustical matters, and which accounted for their neglect in the past, was that one was not able to measure sound in any well-defined unit of energy. Lord Kelvin truthfully said that one never made much progress in any physical science until one could begin to measure. If the lecturer could provide a means for actually measuring sound, the developments which were bound to follow would be very much greater than any other which had been indicated that evening and the whole scientific world would be greatly indebted to the lecturer for having provided a proper sound unit at last.

Sir H. Acton Blake, K.C.M.G. (Deputy Master of Trinity House), said that as head of the administration responsible for producing the sounds which the lecturer had analysed, he wished to quarrel with him because he had not applied all his great knowledge to audibility. The lecturer was trying to make sound visible, but personally he wanted to make sound heard, because when that sound was not heard he got called over the coals for it. He suggested the lecturer should turn his attention to making something which should be a real microphone and which would enable the human ear to listen to the sounds which he himself produced. It was not a bit of use for his purpose being able to throw a light on a screen; the man on lookout could not see it there. He made many mistakes about where sound came from, but he would make many more if he saw a light there.

He could bear out what the lecturer had said as to the effect of fogs in causing echoes. He himself had heard an echo come back off a bank of fog as loud as the original sound, and during the experiments which the lecturer made during the long months he spent at the Station on the North Foreland, he was able to verify what had previously been heard, and not only to verify, but to give some reasons for it which were previously unknown. Therefore, from the point of view of the people who produced the sound he would like to thank the lecturer for his very careful research. Personally, he had had the opportunity of being with the lecturer at the time he took the photographs he had shown at the Casquets, and one thing which struck him more than anything else was the magnificent care and patience with which Major Tucker and his colleagues carried out their work. The lecturer had not mentioned it, but he might say that that work had to be done under extremely difficult conditions, yet nothing was too troublesome for them to attempt to overcome and they overcame it very successfully.

Dr. G. C. Simpson said that as a good deal had been heard that evening about the effect of the work which had been discussed on meteorology, he thought perhaps it would be a good thing if, as a meteorologist, he added his remarks to the discussion. The great explosion in Holland having been mentioned, he thought the members might like to hear news he had received from that country giving the first results of the investigation. As was well-known, the investigation was carried out for a definite scientific purpose. Whenever an explosion had taken place previously, it had been by accident, and it had been found that the sound was heard at great distances and close to its place of origin, but that there had always been a region or belt in which there had been no sound. It had been an extremely difficult scientific problem to explain how that came about. Of course, it had been known for a long time that meteorological factors must affect the propagation of sound. The main causes which affected sound were velocity of wind, temperature and the constitution of the atmosphere. Numerous theories had been propounded to account for the zone of silence, but none of them was satisfactory. It was felt that if an experiment could be made so that the actual observations could be arranged and prepared for beforehand, an interesting result would be obtained.

He had heard that day from Holland that the explosion in question was heard in an E.S.E. direction for 850 kilometers, in a S. direction for 600 kilometers and in a N.W. direction for 750 kilometers—quite long distances. Between 100 and 180 kilometers of the source, however, not a single trustworthy report had been received. That, therefore, provided a very good example of the sound being actually listened for over a large area and still a zone of silence being found. If only an instrument like the lecturer's could have been placed in selected positions over the whole area and the records compared, the experiment would have been of still greater value.

To return to the hot wire microphone, it could not be contended that the lecturer had invented a new meteorological instrument which might be put up in the hall alongside the thermometer and barometer, but still, he had invented an instrument with a great power of investigating sound, and sound was so intimately connected with meteorology that results of meteorological importance must follow. Although one hoped that the instrument would help meteorologists, he thought the lecturer would admit that, up to the present, meteorologists had been able to give him a certain amount of information and help in his work.

He could imagine how glad Professor Tyndall would have been to have had an instrument such as the lecturer's when investigating fog, and there were a number of meteorological

problems the lecturer had not mentioned that evening in which it might be useful, such as finding out the velocity of the air in the upper atmosphere, which was of great importance for many meteorological problems, and also for the application of meteorology to such things as gunfire.

Before sitting down he would like to draw attention to an aspect of the work which, to him, was very striking, namely, that it had been done entirely by Government, at Government expense in a Government Institution. It was practically pure science, and it was, he thought, an interesting sign of the times that Government had worked and was working along those scientific lines. Before the war very little was known of the matter, but now one had the three great fighting forces, the Army, the Navy, and the Air Force, joining together and employing men like the lecturer to investigate scientific problems. What was still more striking was the fact that an investigation which had started with the idea of fixing the position of guns so that not only the guns, but the men working them might be wiped out, had been adapted to things which were of use to the people at large and for the investigation of medical problems and as a help to investigators. It showed that one could not touch any scientific problem even for assistance in war without getting some great advantages for peace.

Dr. L. Isserlis wished to add a last word to emphasize the importance of the lecturer's work from the point of view of the Merchant Service. Personally, he was an official of the Chamber of Shipping of the United Kingdom, and he could testify that it was of the very greatest interest to those connected with merchant shipping to hear that the invention which had been described, and which was originally designed for war purposes, was now proving useful to the Brethren of Trinity House, who were using it in order to differentiate between one type of siren and another. The perfection of the various fog sirens which gave warning to mariners was a matter of the very greatest importance to ship-owners, but, while in that aspect it touched shipowners directly, it also affected them in another way indirectly, in so far as the Meteorological Office, who kept them informed of everything that was happening between the sea and the heavens in the various portions of the globe, were profiting by it. In addition to the kind words which the Chairman, representing the Admiralty, had spoken, he thought it was not out of place to add something as a representative of merchant shipping.

Major Tucker, in reply, said that with regard to the point raised by Mr. A. Campbell Swinton as to the name "microphone," the question of naming the instrument had caused a great deal of heartburning and discussion, and the word "microphone" resulted simply from a difference of opinion among all the people concerned. It was really a measurer of blasts of air caused as a result of sound, but it was extremely difficult to think of a word which was sufficiently simple, without being pedantic, to describe how the instrument worked.

With regard to Sir Acton Blake's remarks, he would like to say that he and his colleagues had very much at heart the kind of work Sir Acton described—how to make sounds audible to the mariner, knowing that the ear was of more importance than any instrument which could be devised. The only way in which he could help in that matter, however, was by devoting his attention to the production of sources of sound, and he was glad to say that his resources had enabled him to follow out that line of work. The application it had was in testing sounds once they had been produced; unfortunately, at the present time, sufficient progress had not been made to enable the microphone to be used with great effect, but that was a matter which was in the forefront of their programme and he hoped they would be able to supply the Elder Brethren with the information they required.

The Chairman said that a very interesting lecture had been followed by a very good discussion, which he hoped would be taken note of by those in authority. He asked the Meeting to accord a hearty vote of thanks to the lecturer for his interesting paper.

The vote of thanks was accorded unanimously and the meeting then terminated.

CORRESPONDENCE.

In the *Journal* of 17th November, page 877, is an article headed "Arghan—A New Textile Material."

This fibre was drawn to the attention of the Royal Society of Arts by E. G. Squiers in 1860 or 1861. Samples also at that time were submitted to the Kew Garden laboratories and to several spinners, all of whom pronounced it equal to the best Belgian flax.

Mr. Dawes, an Englishman, at the head of the Colombian Agricultural Department, later wrote pamphlets for the Colombian Government on this fibre, and re-named it *Pita Colombia* or *Pita Opon.*

The botanists have never properly classified it, and it is variously known under the names of *Bromelia Karatas*, *Bromelia Ananas*, *Bromelia Macradontes* and *Pita Floja.*

The name of *Pita Colombia* is hardly applicable as it grows extensively in all of the Central and South American countries from 15 degrees north to 15 degrees south of the equator. As these tracts are impenetrable, it is difficult to show the depth of them; but by following up the beds of dry streams, running at right

angles to each other for many miles in both directions, I am safe in saying there is enough of this fibre growing wild in Central and South America to supply a half million tons yearly.

This plant belongs to the pineapple family and is really a wild pineapple. There are many varieties called by the natives Penguin, Pinuela, Maya, Chivy-chivy and Pita; Penguin yielding the poorest fibre and Pita the best. Pita is a Spanish term meaning fibre, and is applied generally to many fibre bearing plants, also to any fibre twine.

The leaf of this plant, now called Arghan by British interests, is from six to nine feet long and from three to four inches wide at the butt end, tapering to the tip. Each fibre runs the entire length of the leaf, and is divisible into ten thousandths of an inch. The leaves are a quarter to three-eighths of an inch thick in the centre, tapering towards the edges, which are quite thin, for the space of an inch to each side. This centre thickness also tapers towards the tip of the leaf. Along the edges are many sharp hook-shaped thorns pointing both up and down, making the leaves difficult to handle.

The Indians clean it by placing the leaf on a flat board and rubbing off the pithy surface with a round edged piece of metal or hard wood; then washing and drying it in the sun. The results from this method of cleaning were too small to make the fibre a commercial possibility until the invention of a machine in 1918 by an American inventor (reported on by the American Consul in Colombia in 1920) proved it could be mechanically cleaned in commercial quantities.

Mr. Henry Wilson, of the Belfast Rope Works, examined these machines about a year ago, and their advent has given a great impetus to those interested in the fibre.

The American Company known as the Tropical Fibre Corporation, has built over one hundred machines, and are now contemplating an additional thousand.

G. A. Lowry,
Room 1021, 15, Williams Street,
New York City, U.S.A.

December 11th, 1922.

HYDRO-ELECTRIC DEVELOPMENT IN AUSTRALIA.

The general conception of Australia seems to be that of a riverless, lakeless country in which possibilities for development of hydro-electric power are practically non-existent. This is true for a considerable part of the continent, but quite the opposite for the mountainous island State of Tasmania, and decidedly to be qualified in respect to northern Victoria, eastern New South Wales, and north Queensland. The contiguous mountains of New South Wales and Victoria are broken by deep narrow valleys, through which small but swift and steadily flowing rivers run; and plans for their development have in many cases been prepared. Barron Falls in north Queensland, will some day be the site of a water-power development which will revolutionize that rather desolate but rich region. Tasmania is already well advanced electrically.

According to an interesting report by the United States Trade Commissioner lately at Melbourne, the hydro-electric development at Tasmanian Great Lake—one of the most interesting natural water powers in the world—was begun before the war as a private enterprise by the Hydro-Electric Power and Metallurgical Co. Because of financial difficulties, the company was compelled in 1914 to transfer its rights to the Government of Tasmania, which had made the company large advances. The State proceeded with the development, and in 1917 made a contract to supply the Electrolytic Zinc Corporation with power up to 30,000 horsepower at £2 per horsepower per annum. This new organisation, the stock in which is owned by all the zinc-producing companies of Australia, has at Risdon (a suburb of Hobart) the largest electrolytic zinc works in existence. To this plant electric power generated at the Great Lake is transmitted by high-tension lines, and to it also are transported zinc concentrates from Broken Hill (New South Wales) and elsewhere. The plant production is 120 slabs of zinc a day, an output which on the completion of two new units will be doubled.

The State further supplies power to the company which originated the Great Lake Scheme and which is now manufacturing carbide on a large scale at Hobart. Besides keeping these two important industries going, Great Lake power operates the street cars and electric lights of Hobart. It will be used also by two new woollen mills and other industrial enterprises, as well as by the new Cadbury-Fry chocolate factory at Hobart, and by the Waterloo Chemical Works, which is about to begin the electrolytic manufacture of pigments from scrap iron. Launceston, as well as Hobart, is to have the use of power from the lake as soon as the transmission line north, now in course of erection, is completed.

The Great Lake of Tasmania is situated almost in the centre of the island, about equidistant (62 miles) from Hobart on the south coast and Launceston on the north coast, the two chief cities and ports of Tasmania. The lake is about 3,900 feet above the sea level—a great natural reservoir in a large plateau traversed by two rivers, the Shannon and the Ouse. The Shannon is the natural outlet of the lake, the level of which was raised 11 feet in 1914 by a dam at the entrance to the Shannon. In 1921 a diversion canal was completed carrying the Ouse into the lake, and concurrently a new dam was built just below the old one, raising the lake level another 29 feet.

The River Shannon, confined between banks artificially raised to provide for the increased flow of water, runs about 12 miles to a pool whence it is conveyed through wooden flumes to Waddamanna. There it drops 1,100 feet perpendicularly through iron flumes to the power house, the equipment of which at the time of the Trade Commissioner's last visit to Waddamanna was generating 18,000 horse power. Two additional 9,000 horse-power turbine generators were then being installed to double the output of power. The whole plant is to be redoubled within the next year or two, raising the horsepower to 72,000.

The Electrolytic Zinc Corporation is entitled by its contract to 30,000 horsepower, 22,000 horsepower will be divided between the city of Hobart and industrial enterprises there, and 10,000 will be allocated to Launceston. The latter city has its own separate hydro-electric power, obtained by damming the small stream which runs through the extremely picturesque gorge on the edge of the city and used for the operation of car lines, but this power is insufficient for the needs of the growing community.

By connecting Lake Arthur with the Great Lake, it is believed the power generated at Waddamanna can by raised to 85,000 and, by further extension of the drainage basin, to 100,000 horsepower when necessary.

On the west coast of Tasmania the Mount Lyell Railway and Mining Co. has an independent 10,000 horse-power hydro-electric system, supplying its own power requirements; the surplus is sold to the Mount Read-Roseberry mines and to the village of Queenstown. This system is believed to be capable of considerable expansion. Several sources of water power have also been recently surveyed in the tin-mining regions of the north-east coast. The total estimated possible hydro-electric power of the island exceeds 200,000 horsepower.

In both Victoria and New South Wales a number of important irrigation systems are operating, some of which may be developed into power schemes, though nowhere is the present fall at the dam very great. New South Wales has authorised appropriations to begin work on power dams at Burrenjuck and on the Nymboida, their cost when completed being estimated at £1,000,000. It is proposed also to establish an inter-state power plant at the Hume Reservoir of the Murray Waters system, now being created by the States of New South Wales, Victoria, and South Australia, with the assistance of the Commonwealth Government. Such a plant, it is expected, would make the border town of Albury a big industrial centre, it being now the centre of a large wool and wheat growing area.

Not far from Albury, in Victoria, is a power site called Kiewa, from the mountain born river of that name rising near the Bogdo High Plains and falling through a valley apparently easily dammed. The people of northern Victoria have agitated vigorously for Kiewa development, plans of which have been officially published, but the State authorities being committed to the Morwell brown coal electric power scheme cannot take up Kiewa at present. They have, however, authorised private exploitation of the Kiewa Valley, but only on condition that no power from there be sold in competition with Morwell power, which should be sufficient for all the needs of Melbourne and Victoria generally, perhaps as far north as Bendigo. A further condition is that Kiewa plant, if erected by private capital, shall become State property in 20 years. It is improbable, in the Trade Commissioner's opinion, that anything will be done at Kiewa, except by the State, and after completion of the Morwell enterprise in about three years.

No estimate has been made, as far as the Trade Commissioner is aware, of the power available from Barron Falls, in north Queensland, which are only 19 miles from the coast and the sugar port of Cairns. The sheer drop of these beautiful falls is 375 feet; the total drop, by a series of cascades, is 830 feet within 100 yards; and the total elevation of the top of the falls above the sea level is 1,060 feet. The volume of water coming over these falls in the wet season is very great: even in dry times it is enough to generate much power. Adjacent to Barron Falls are not only the main Queensland sugar-cane fields, which are producing this year 278,000 tons of raw sugar, but also large undeveloped forests and mining areas. It is possible that concessions to work the falls jointly with the forests and the mines may be obtained from the Queensland Government.

INDIAN BARLEY FOR MALTING.

At one time large quantities of barley were sent to this country from India for use in the brewing industry. In 1912-13 for example, nearly 300,000 tons of a total value of about 1¾ million pounds sterling, were shipped from the various ports. About two-thirds of this supply came from Karachi, slightly less than one third from Calcutta and a small quantity from Bombay.

In 1913 the attention of the Cereals Committee of the Imperial Institute was drawn to the fact that early shipments of Indian barley germinated well, while the latter shipments were liable to contain a large percentage of grains that would not germinate, sometimes amounting to 10 or even 20 per cent. The investigation of the question by the committee indicated that it was probable that the barley which suffered injury was that which failed to get railed and shipped before the monsoon set in and was consequently stored in cultivators' pits and huts, and that the damage was caused by the humidity and warmth of the rainy season,

followed by the drying of the barley before it reached England. As this defect lowered the value of the barley for malting purposes the matter was referred to the Department of Agriculture, United Provinces, with the suggestion that the matter should be investigated.

Experiments on the influence of atmospheric conditions on the germination of Indian barley have now been carred out by Mr. W. Youngman, B.Sc., Government Economic Botanist, United Provinces, and the results, which have been published as a memoir of the Indian Department of agriculture, are summarised in the current number of the "Bulletin of the Imperial Institute." It was found that if barley is exposed for some time to an atmosphere containing a large amount of moisture, the germinating capacity of the grain is seriously reduced and may even be destroyed entirely. Such a condition of the atmosphere exists in North-Eastern India during the period of the monsoon, i.e., after May, and consequently the germinating power of barley shipped from Calcutta after May is liable to be low. Barley produced in north-western and central India would not meet with adverse conditions at any time of the year, and although the humidity of the atmosphere along the sea-board area from Karachi to Bombay is high after May, barley exported at that period from these ports would not suffer appreciably if it were not delayed long in the seaboard area. In view of these circumstances Mr. Youngman considers that, after May, the grain should not be shipped from Calcutta, but that it should be transported from the danger zone towards Karachi or Bombay not later than the end of June.

No barley has been exported to this country from India during the last 3 or 4 years, but when shipments are again made it would be well for the results of this work to be borne in mind.

GENERAL NOTES

Agricultural Developments in the Gold Coast.—The principal industry in the Gold Coast is the production of cocoa, the exports of which constitute about one-fourth of the world's commercial supply and have an annual value of over £10,000,000. The crop is grown entirely by natives. Attempts are being made by the authorities to assist the natives in parts of the Colony where cocoa is not grown by introducing new agricultural industries, and an interesting account of these developments, prepared by the Deputy Director of Agriculture, is given in the current issue of the Bulletin of the Imperial Institute. Along the 300 miles of sea-coast there is much land suitable for the planting of coconuts, which at present are only grown to a small extent in the Eastern Province. The Government have obtained on loan from the local chiefs plantations of 300 acres each in the Western and Central Provinces, and small ones amounting in the aggregate to 300 acres in the Eastern Province. The land is being planted with coconuts, and drying houses and store houses are being erected for the preparation of copra (the dried coconut from which coconut oil is obtained). It is hoped in this way to demonstrate that a profitable industry can be built up as an adjunct to the fishing industry, which is at present the principal occupation of the coast natives. When the cost of establishment has been recovered the Government propose to hand the whole concern over to the native chiefs for the benefit of their communities. Similar action is being taken in connection with the introduction of Sisal hemp, which promises to do well in certain parts of the Colony. A plantation of 1,000 acres is being used as a demonstration area, and in this case also, when the cost of establishment has been met, the plantation, complete with decorticating machinery, tram-lines and all other accessories, will be handed over to the local chief and his people for their own benefit.

Rubber for Road-Surfaces.—Experiments are being carried out in Ceylon by the Colombo municipality in the use of rubber as a road-surface dressing. The dressing, which is the invention of a Ceylon rubber planter, is now being used on a portion of Darley Road, which is one of the busiest thoroughfares in Colombo. The solution was first tried on a road of the Devitural rubber estate, where it has been in use for the past thirteen months. The present test, according to the *British Trade Journal*, is the hardest to which the new solution has been put. The solution is made from pure bark and scrap rubber. The method of laying is similar to that employed with tar and asphalt preparations, it being heated until liquid, and then spread on the road with brooms. Fine gravel is then sprinkled over the solution and a steam roller binds the two. It is claimed that though the cost of the liquid rubber is higher than tar, it is found to last twice as long.

River Gauging.—A Committee on Gauging Rivers and Tidal Currents has been appointed by the Department of Scientific and Industrial Research to collect information relating to methods and appliances used in investigations bearing upon measurements of river, tidal and other currents and to the testing and standardisation of such apparatus, and to test appliances that appear to be suitable for use in the study of the water power resources of this country. Under the direction of the Committee a report has been prepared which summarises the information available as to the conditions affecting the design and use of current meters, and gives a description of the types now in use.

MUSK TRADE OF CHINA.—The Chinese musk export trade is practically controlled by four large firms in Shanghai, Tachinglu, the principal point of collection, and Chungking, the chief port of original export of this commodity. There are, however, writes the United States Vice-Consul at Chungking, numerous minor firms engaged in supplying the local demand. In spite of the unsettled political conditions along the Szechwan-Tibetan border, the export of musk from Chungking has increased somewhat since the close of the European War, amounting in 1920 to about 3,600 pounds, valued at 577,079 haikwan taels (about £144,000). The United States, instead of France, during 1920 was the leading customer, being credited with 33⅓ per cent. of the shipments; Japan took 25 per cent., Hong Kong 20 per cent., and France 12½ per cent. During the first nine months of 1921, Chungking's exports were 1,040 pounds, as against 920 pounds for the same period of 1920.

DISCOVERY OF TRIPOLI EARTH IN TACNA.—In Tacna Province, Chile, deposits of high-grade tripoli earth (Kielselguhr) have recently been discovered, writes the United States Consul at Arica. A French mining engineer gave as his opinion that the tripoli earth in question was of the best quality and especially fine for glazing china. Several trial shipments, aggregating 25 metric tons, have been made to South Chile. In addition to its use as stated above, it may be used in the manufacture of dynamite.

MEETINGS OF THE SOCIETY

ORDINARY MEETINGS.

Wednesday evenings, at 8 p.m. :—

JANUARY 17.—C. A. KLEIN, "Hygienic Methods in Painting—the damp Rubbing-down Process." THOMAS MORISON LEGGE, C.B.E., M.D., D.P.H., H.M. Medical Inspector of Factories, will preside.

JANUARY 24.—SIR WILLIAM HENRY BRAGG, K.B.E., M.A., D.Sc., F.R.S., Quain Professor of Physics, University of London, "The New Methods of Crystal Analysis, and their Bearing on Pure and Applied Science." (Trueman Wood Lecture). ALAN A. CAMPBELL SWINTON, F.R.S., late Chairman of the Council, will preside.

JANUARY 31.—THOMAS H. FAIRBROTHER M.Sc., F.I.C., and ARNOLD RENSHAW, M.D., D.P.H., "The relation between Chemical Constitution and Antiseptic Action in the Coal Tar Dyes."

FEBRUARY 7.—CHARLES R. DARLING, F.Inst.P., A.R.C.Sc.I., "Electrical Resistance Furnaces and their Uses." SIR ROBERT A. HADFIELD, BT., D.Sc., F.R.S., will preside.

FEBRUARY 14.—W. J. REES, Lecturer on Refractories in the University of Sheffield, "Progress in the Manufacture of Refractories."

FEBRUARY 21.—C. AINSWORTH MITCHELL, M.A., F.I.C., "Handwriting and its value as Evidence." SIR RICHARD D. MUIR will preside.

FEBRUARY 28.—PROFESSOR W. E. S. TURNER, D.Sc., Head of Department of Glass Technology, The University, Sheffield, "Heat Resisting Glasses."

MARCH 7.—

MARCH 14.—SIR WILLIAM WARRENDER MACKENZIE, K.B.E., K.C., President of the Industrial Court, "Industrial Arbitration." LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, will preside.

INDIAN SECTION.

Friday afternoons at 4.30 o'clock.

JANUARY 19.—THE RT. HON. THE EARL OF RONALDSHAY, G.C.S.I., G.C.I.E., late Governor of Bengal, "A Clash of Ideals as a Source of Indian Unrest." The RT. HON. VISCOUNT PEEL, G.B.E., Secretary of State for India, will preside.

FEBRUARY 16.—J. T. MARTEN, I.C.S., M.A., Imperial Census Commissioner in India, "The Indian Census of 1921." SIR EDWARD A. GAIT, K.C.S.I., C.I.E., Member of the India Council, will preside.

JUNE 15.—SIR JOHN H. MARSHALL, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture).

DOMINIONS AND COLONIES AND INDIAN SECTIONS.

MARCH 16.—Lieut.-Col. SIR LEONARD ROGERS, C.I.E., F.R.S., F.R.C.P., F.R.C.S., Physician and Lecturer, London School of Tropical Medicine, "Recent Advances towards the Solution of the Leprosy Problem."

APRIL 20.—SIR RICHARD A. S. REDMAYNE, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S., "The Base Metal Resources of the British Empire."

MAY 1.—L. GUY RADCLIFFE, M.Sc. (Tech.), F.I.C., "The Essential Oils of the British Empire."

Dates to be hereafter announced:

WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Recent Developments in Surface Combustion."

EDWARD PERCY STEBBING, M.A., F.L.S., Professor of Forestry, University of Edinburgh, "The Forests of Russia."

MAURICE DRAKE, "The Development of Mediæval Technique in Stained Glass Windows."

EDWARD PARNELL, "The Resources and Trade of Sarawak."

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

HENRY P. STEVENS, M.A., Ph.D., F.I.C., "The Vulcanisation of Rubber." Three Lectures. February 5, 12, 19.

J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards, "Length Measurement." Three Lectures. March 5, 12, 19.

SAMUEL A. DAVIES, Chemical Department, Messrs. Rowntree & Co., York, "Cocoa and Chocolate." Three Lectures. April 9, 16, 23.

HOWARD LECTURES.

Monday evenings at 8 o'clock.

STANLEY S. COOK, "Recent Improvement in Steam Turbines." Three Lectures. April 30. May 7, 14.

DR. MANN JUVENILE LECTURES.

Wednesday Afternoons, at 3 o'clock.

CHARLES R. DARLING, A.R.C.Sc.I., F.I.C., "The Spectrum, its Colours, Lines and Invisible Parts, and Some of its Industrial Applications." Second Lecture January 10.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK

MONDAY, JANUARY 8 .. Surveyors' Institution, 12, Great George Street, S.W., 8 p.m.

Brewing, Institute of (London Section), 30, Russell Square, W.C., 8 p.m. Mr. J. Stewart, "The Season's Barleys."

Architectural Association, 34, Bedford Square, W.C., 7.30 p.m. Mr. L. A Turner, "The Workshop."

Chemical Industry, Society of, joint meeting with the Bio-Chemical Society, at the Institution of Mechanical Engineers, Storey's Gate, S.W., 5 p.m. to 7 p.m., 8.15 p.m. to 10 p.m. Discussion on "Micro-Organisms and their application to Industry and Research," to be opened by Sir William Pope.

Engineers, Cleveland Institution of, Technical Institute, Middlesbrough, 6.30 p.m.

TUESDAY, JANUARY 9 .. Metals, Institute of (Scottish Section), 38, Elmbank Crescent, Glasgow, 7.30 p.m. Professor F. C. Thompson, "The Heat Treatment of Some Industrial Non-Ferrous Alloys." (Birmingham Section), Chamber of Commerce, New Street, Birmingham, 7 p.m. Dr. H. B. Keene, "X-Rays and Crystal Structure."

Civil Engineers, Institution of, Great George Street, S.W., 6 p.m.

Swiney Lectures, at the Imperial College of Science, Exhibition Road, S.W., 5.30 p.m., Professor T. J. Jehu, "Fossils and What They Teach" (Lecture X.)

Royal Institution, Albemarle Street, W., 3 p.m. (Juvenile Lecture). Professor H. H. Turner, "Six Steps up the Ladder to the Stars." (Lecture VI.)

Colonial Institute, Hotel Victoria, Northumberland Avenue, W.C., 8.30 p.m. Sir Joseph Cook, "The Third Assembly of the League of Nations."

WEDNESDAY, JANUARY 10 .. Geological Society, Burlington House, Piccadilly, W., 5.30 p.m.

United Service Institution, Whitehall, S.W., 3 p.m. Captain E. Altham, "The Dwina Campaign."

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C., 6 p.m. (Wireless Section). Mr. C. F. Elwell, "Design of Radio Towers and Masts: Wind Pressure Assumptions."

THURSDAY, JANUARY 11 .. Aeronautical Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 3 p.m. (Juvenile Lecture). Mr. R. A. Frazer, "Model Aircraft."

Historical Society, 22, Russell Square, W.C. 5 p.m. Mr. R. A. Roberts, "The Birth of an American State, Georgia; An Effort of Philanthropy and Protestant Propaganda."

Optical Society, at the Imperial College of Science, South Kensington, S.W., 7.30 p.m.

Camera Club, 17, John Street, Adelphi, W.C., 8.15 p.m. Mr. J. S. Wells "Criticism of Members' Prints."

Mechanical Engineers, Institution of (South Wales Branch), Park Place, Cardiff, 7.30 p.m. Annual Meeting.

Swiney Lectures, at the Imperial College of Science, South Kensington, S.W., 5.30 p.m. Professor T. J. Jehu, "Fossils and What They Teach." (Lecture XI.)

Metals, Institute of, at the Institute of Marine Engineers, 85, Minories, E., 8. p.m. Mr. W. E. Hughes, "Some Aspects of Electro-deposition."

Dyers and Colorists, Society of (Bradford Junior Section), Technical College, Bradford, 7 p.m. (1). Mr. H. Robinson, "Resist Effects on Yarn" (2). Mr. K. A. Dixon, "Acetyl Silk."

FRIDAY, JANUARY 12 .. London Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5 p.m. Mr. J. P. Orr, "The Transport and Open Space Problems in City Development."

Swiney Lectures, at the Imperial College of Science, South Kensington, S.W., 5.30 p.m. Professor T. J. Jehu, "Fossils and What They Teach." (Lecture XII.)

Dyers and Colorists, Society of (Scottish Section), Glasgow, 7 p.m. Mr. D. Brownlie, "Steam Efficiency in the Dyeing and Allied Industries."

Timber Trade Lectures, Council Chamber, London Chamber of Commerce, Oxford Court, Cannon Street, E.C., 6.30 p.m. Mr. G. A. Farber, "American Hardwood Forests and Saw Mills, from 1895 to 1921."

Malacological Society, at the Linnean Society, Burlington House, Piccadilly, W., 8 p.m.

Astronomical Society, Burlington House, Piccadilly, W., 5 p.m.

Birkbeck College, Anglo-Batavian Society, Bream's Buildings, Chancery Lane, W.C., 6 p.m. Dr. T. E. Gregory, "The Dutch In and Out of Europe."

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

NOTICES.

NEXT WEEK

WEDNESDAY, JANUARY 17th, at 8 p.m. (Ordinary Meeting.) C. A. KLEIN, "Hygienic Methods in Painting—The Damp Rubbing-down Process." THOMAS MORISON LEGGE, C.B.E., M.D., D.P.H., H.M. Medical Inspector of Factories, will preside.

FRIDAY, JANUARY 19th, at 4.30 p.m. (Indian Section.) THE EARL OF RONALDSHAY, P.C., G.C.S.I., G.C.I.E., late Governor of Bengal, "A Clash of Ideals as a Source of Indian Unrest." The RIGHT HON. VISCOUNT PEEL, G.B.E., Secretary of State for India, will preside.

Further particulars of the Society's meetings will be found at the end of this number.

BINDING COVERS FOR JOURNALS.

For the convenience of Fellows wishing to bind their annual volumes of the *Journal*, cloth covers can be supplied, post free, for 2*s*. each, on application to the Secretary.

ANN JUVENILE LECTURES.

The second of the series of Juvenile Lectures under the Dr. Mann Trust was commenced on Wednesday, January 3rd., by MR. CHARLES R. DARLING, F.INST.P., A.R.C.Sc.I., F.I.C., the subject being "The Spectrum, its Colours, Lines and Invisible Parts, and some of its Industrial Applications." The chair was taken by MR. ALAN A. CAMPBELL SWINTON, F.R.S., a Vice-President of the Society.

Mr. Darling described briefly the nature of light waves. These were caused by minute particles of electricity called electrons, which flew about in all directions through the ether. Whenever any obstacle got in their way and changed their speed, waves were set up and these waves helped to make what we called light; so that light was really only a kind of wave.

He exhibited a model representing the action of the eye, and explained how the waves of light were received by the retina and conveyed by the nerves to the brain. Light of different colours came from waves of different lengths. From long waves we obtained red light, from shorter ones green, and from still shorter ones blue; the difference in colour being really due to difference in the length of the waves. When the waves fell upon the eye, the brain interpreted the waves and gave us the impression of a certain colour. An image was formed at the back of the eye and was conveyed to the brain. It was not done immediately. It took a certain amount of time and was like the process of sending a telegram from the back of the eye to the brain. If a lot of colours fell upon the eye very rapidly one after the other, instead of seeing the separate colours, they became blurred and strange effects were produced. This phenomenon was illustrated by means of a revolving disc, the separate bands of colour disappearing when the disc was turned quickly and re-appearing as it slowed down again. If a certain number of colours were taken and mixed all together we got white, and if we mixed various colours, very strange results might be obtained. He mentioned that some years ago a beautiful specimen of a butterfly was sent over from India by a gentleman who said it was very difficult to distinguish when flying. When seen at rest it was a most gaudily coloured insect, but when it was flying the colours all blended together and became khaki. It was very difficult to observe it when flying rapidly, but the moment it was at rest the gay colours made their appearance again.

Sunlight and electric light, although they looked white, were really a mixture of colours. The waves sent out were of different sizes or lengths, and a ray of white light could be broken up into its constituent colours by passing it through a lens. Nature had been doing this ever since the first shower of rain fell upon the ground and gave us a rainbow, which was caused by the drops of rain sifting the light from the sun and separating it into its different colours. Illustrations of the effect of a revolving wheel of different colours and of a rainbow were then thrown upon the screen. Sir Isaac Newton discovered the cause of the rainbow by conducting experiments with wedges or prisms of glass which broke up the light into the various shades, and his experiments had led to extraordinary results in many branches of science. A rain drop behaved like a kind of prism and the colours in the rainbow were just the same as those we got in a prism. The colours of the spectrum were then shown upon the screen by means of a prism and a special kind of mirror upon which lines, 14,000 to the inch, were ruled. These mirrors, known as gratings, were very much better to work with than a prism.

After this, interesting illustrations were exhibited showing the action of different colours and their power of stopping or absorbing certain kinds of colours. The lecturer also di-played by means of an ingenious machine the results of the mixture of various colours and the difference in the tints caused by the separation of one part of the spectrum from the remainder. He next referred to colour-blindness and by the use of a greenish tinted glass, coloured ribbons, paper caps, and a dish of fruit, some very striking examples of the apparent changes in colour observed by persons suffering from this defect were shown. The lecturer then demonstrated the effects of light obtained from vapours. Silver and copper, instead of carbon, were burned in a lamp and the effect of the flames upon the spectrum projected upon the screen. Different lines in the spectrum were distinctly shown and each kind of metal burnt produced different lines. By studying the lines thus obtained, Mr. Darling said they could find out what the sun and stars contained—copper, gold or silver, &c.; so that the sun had not only been sending us light for thousands of years, but had been telling us all the time what it was made of.

PROCEEDINGS OF THE SOCIETY.

SIXTH ORDINARY MEETING.

WEDNESDAY, DECEMBER 13TH, 1922.

THE EARL OF CRAWFORD AND BALCARRES, K.T., P.C., F.S.A. in the chair.

The paper read was:—

THE LOSS OF COLOUR IN OBJECTS EXPOSED TO LIGHT.

By SIR SIDNEY F. HARMER, K.B.E., Sc.D., V.P.R.S.,

Director of the Natural History Departments of the British Museum.

The occurrence of fading in objects exposed to strong sunlight is a matter of common knowledge. It is a subject of special practical importance in museums, and as one who has considerable responsi-bilities in this connexion, it appeared to me desirable to make a few simple experi-ments in order to satisfy myself with regard to the kinds of light which were most injurious, and to examine the question whether pigmented objects could be pro-tected by keeping them in light rendered less innocuous by the removal of the actinic rays. My results have been recorded in *The Museums Journal*, Vol. xxi., 1922, *pp.* 205-222; and I have there referred to some valuable experiments which were described by Dr. W. J. Russell and Sir W. de W. Abney in 1888 and 1914, the later paper having been published in Vol. lxiii. of the Society's Journal. The "Report of the Committee on Leather for Book-Binding," edited for the Society of Arts and the Worshipful Company of Leathersellers by Viscount Cobham and Sir Henry Trueman Wood (London, 1905), also contains important observations on alterations due to the action of light on materials. The preservation of the colours of valuable objects is of so much importance to private individuals, as well as to museum curators, that I have been asked to make my results more widely known by placing them before the Royal Society of Arts.

One of the special questions to be investigated was the relative injuriousness of the different methods of illumination, as ordinarily in use: the question, for instance, how far diffused daylight is capable of producing the effects known to result from an exposure to direct sunlight. It appeared desirable, moreover, to obtain

further information as to the extent of the fading which may occur in objects exposed to electric light, whether to arc-lights or to incandescent lights. In view of the great alterations which are known to be produced by the actinic rays at the violet end of the spectrum, it was important to ascertain whether protection, complete or partial, could be afforded by filtering off these rays by the aid of tinted glasses. These were the main objects of my enquiry; and the prospect of success in making use of tinted glasses had been indicated by the earlier experiments of Dr. Russell and Sir William Abney.

The colour of objects may be due to more than one cause. The present account refers exclusively to colours produced by the presence of definite pigments, and it has no relation to colours, such as those of a soap-bubble, which are produced by "interference" of light-rays in very thin films. In selecting objects for experiment it was natural to make use of pigments known to be fugitive; since definite results could be obtained from more permanent colours only with a very prolonged series of observations. The pigments actually used have thus been suitable aniline colours and other artists' pigments, as well as organic pigments, in the skin-derivatives of animals, known from experience to be readily altered by light.

Dr. Russell and Sir William Abney had arrived at certain definite results, the most important of which, from a practical point of view, were the following:—(1), fading is due to the action of light, and not to that of moderate heat of the kind produced by exposure even to the strongest sunlight; (2), it does not take place *in vacuo, i.e.*, in the absence of oxygen and moisture; (3), the rays at the violet end of the spectrum produce the greatest amount of fading. The second of these results indicates that fading is ordinarily a chemical process, due to the oxidation of the pigments. Sir William Abney believed it to be due to ozone, but he found that the oxidation occurred only in the presence of moisture. If oxygen and moisture could be completely excluded, even the most fugitive pigments would not fade in the brightest sunlight. An experiment which may be suggested to test this result would be to line one half of a gas-filled electric globe with a specially fugitive pigment, and to ascertain whether the colour remained unaltered, after a prolonged exposure to electric light, and later, when the globe was worn out, to direct sunlight. The third result indicated above seemed to afford a definite promise of success by using light-filters which absorb the rays at the blue end of the spectrum.

My own experiments were designed to test simultaneously the two main objects in view; the relative injuriousness of different methods of illumination, and the efficiency of tinted glasses. They lasted over a period of seven years, in two series. The first extended from July 1st, 1914, to April 26th, 1917, and the specimens used had a maximum exposure of 1,030 days, or a litt e more than 147 weeks. It was discontinued in order to substitute a method better designed to obtain comparable results, having the further advantage that the faded objects could be preserved at different stages of the process. This second series lasted from May 4th, 1917, to May 28th, 1921, a period of more than four years, with a maximum exposure of 1,485 days. The objects under observation were placed on easels or in a vertical or horizontal position, according to the source of the light, in rooms which were, as a rule, not continuously lighted. In the case of one exposure, in the 1914 series, they were exposed to the light of an incandescent filament lamp of 40 c.p., kept alight continuously throughout the experiment. In the other electric light exposures the light was turned on for a certain number of hours on each week-day. It is obvious that the exposures to sunlight or diffused daylight were interrupted every night, and I am not able, from the conditions under which the experiments were performed, to give an exact statement of the number of hours during which a specimen was actually exposed to light. It is clear, moreover, that the intensity of the natural light varied according to the season and the weather. It is thus not possible to arrive at quantitative results of any precision from the observations made, although it would be easy, even though somewhat tedious, to employ the methods actually used in such a way that the number of hours during which the exposure lasted was definitely known, while a record could be kept of the number of hours of brilliant sunshine. The greater part of the experiments went on during the War, and there were other more important things to be done which prevented continuous observa-

tion; while the necessity for economy in the use of electric light was a reason for not keeping these exposures continuous. The actual observations required a good deal of time, and the calls of other duties, both during the War and after it, have been responsible for prolonged gaps in the continuity of the recorded observations.

In each series of experiments I made use of tinted glasses, which had been manufactured with the express object of cutting off the rays of the violet end of the spectrum, and particularly the ultra-violet rays. These were kindly supplied, for the experiments, by Messrs. Chance Brothers and Co., Ltd. (Glass Works, Smethwick, Birmingham). The slide shown indicates the amount of absorption which takes place in each of these glasses, or rather the amount of light of different wave-lengths which each transmits. Window-glass transmits practically the whole of the spectrum, including nearly all the ultra-violet rays. If these were the sole cause of fading it would be safe to assume that glass of this kind would have practically no protective value. At the other end of the series is a glass designated as "38," and of a very decided yellow-green colour, which cuts off the whole of the ultra-violet part of the spectrum, nearly all the violet part, and most of the blue rays. An intelligent anticipation of the results would indicate this as the most effective glass for the prevention of fading. Between these two extremes were the following glasses:—Crookes "A," with hardly any colour, and Crookes "B," of a very dark colour (designated respectively as "CA," "CB"), and three glasses of a light yellowish green or yellowish tinge, designated respectively as "AL," "AD" (a darker shade of the same), and "B." The glass 38 is of so strong a colour that it could hardly be used in practice, except for the exhibition of an object which might be exposed to public view under colours far removed from its real ones. CB would be found too dark for many purposes, but CA, AL, AD and B could be used, either in windows or in the glass immediately covering an object, without producing a very noticeable effect either in the quality of the colours of the object or in the intensity of the light transmitted.

Series 1914.

The general plan of these experiments, which lasted for nearly three years, was the exposure of the requisite number of sets of specimens, as nearly alike as possible, to varying conditions of illumination. For this purpose use was made of shallow boxes divided into eight compartments, each covered by a glass strip and all the glasses being of different kinds. Each box was exposed for a prolonged period to one sort of light, direct sunlight, diffused daylight or electric light, the specimens being examined at intervals, and the results noted as accurately as possible on each occasion. They were then subjected to a further period of exposure, the conditions of the experiment being such that at any stage the records of the earlier stages had been obliterated. It was very difficult, moreover, to make descriptive notes having a definite value with regard to the amount of fading. The difficulty would have been overcome by the use of Lovibond's Tintometer in estimating the results; but this would have required much more time than was at my disposal. In spite of these disadvantages the experiment yielded some results of interest.

As confirming the conclusions of Dr. Russell and Sir William Abney it was found that the control set of specimens, which had been completely protected from the light by blackened glass, remained unaltered at the end of the three years. The black glass naturally became strongly heated when exposed directly to the summer sun, but even in the atmosphere thus heated no fading took place. There is, hence, good reason to infer that the fading observed in other specimens resulted from the action of light and not of heat. The effect of moisture was partially examined by keeping certain specimens in compartments in which calcium chloride was present, to absorb moisture. These particular observations were by no means complete, but they indicated that the additional dryness of the air produced by the presence of calcium chloride had afforded some protection to the colours. I see no reason to doubt the conclusion of Dr. Russell and Sir William Abney that even fugitive colours will not fade, even in a strong light, if kept completely protected from oxygen and moisture. As a point of practical importance to Museums in which it is necessary to protect specimens from attack by moths, the effect of camphor in the air was examined to some extent. No material difference was recorded between specimens in a compartment containing camphor and those without camphor, when

exposed to the same illumination. As the effect of this preservative seemed to be negligible in practice, the observations on the subject were not carried further.

As was anticipated, the experiment emphasised, in the most conclusive manner, the more injurious effect of direct sunlight than that of any other form of illuminant. Not only did the fading commence sooner, but it was more complete at all the earlier stages of the observations. Neither diffused daylight nor any form of electric light had a fading effect approaching that produced by direct sunlight. The comparison of diffused light and electric light showed that, from the protective point of view, electric light had some advantages over diffused daylight; the fading caused even by an arc-light of high intensity being on the whole slightly less, or at any rate not greater, than that which results from exposure to daylight in an ordinary room where care is taken to protect the colours from the incidence of the direct rays of the sun.

With regard to the question of the protective value of tinted glasses, it may be noted that it was possible to arrange these in an order of merit corresponding closely enough with the theoretical anticipation based on the assumption that the rays most effective in producing fading are those at the violet end of the spectrum, including the ultra-violet rays. Thus the glass giving the greatest amount of protection was 38, which does not permit the transmission of these rays. Window-glass afforded little or no protection, while the efficiency of the others depended largely on the extent to which they cut off the blue, violet and ultra-violet rays, but partly on the percentage amount of the light of all kinds transmitted by them. But although 38 had a manifest superiority to all the others, and although these were not uniformly good or bad, the general result was reached that even the best of the tinted glasses merely delays fading and does not prevent it, in the case of really fugitive colours. It is not improbable that there are colours so "fast" that the protection afforded by a suitable glass might be permanent; but in the case of others a prolonged exposure to light filtered through a tinted glass will produce the same effect as a short exposure to light which is not so filtered. A museum specimen must be prepared to last for many years, and the mere delaying of its fading may in the long run prove of little value.

SERIES 1917.

Although the first experiment had afforded some results of interest, it had certain disadvantages, and conspicuously the fact that it was not possible to preserve for reference the various stages of the fading of an object. The second experiment was devised to remedy this defect, and its general plan was the utilisation of narrow wooden slips to which the pigmented objects could be affixed. Artists' colours so used were painted in uniform washes on white paper, from which strips to be attached to the wooden slips were cut. These could be prepared in unlimited numbers, and in making observations on a particular pigment the experiment would commence with the exposure of a convenient number of identical slips which could be removed and kept in the dark at successive stages of the experiment, so that the results could be compared at its conclusion. This plan worked admirably in practice, and it permitted the easy comparison of the fading produced by different exposures to the same kind of light or of that resulting from exposures to different kinds of light. The strips were exposed in a set of identical boxes, each 20 by 9⅝ by 1 inches in outside measurements, and provided with a lid glazed with window glass, to exclude dust. Each box was sub-divided by a partition, placed transversely to its greatest length, giving room in each half for four longitudinally arranged strips of glass measuring 9 by 2 inches. Half an inch of each lateral margin of the glass was blackened, and black paper strips were pasted on the inner side of the glass lid, in such a way as to cover the blackened edges of the glasses. The object of these paper strips was to exclude the light which would otherwise have penetrated between the opposed edges of the glass strips. The pigmented slips measured 8 by ¾ inches and were arranged at right angles to the long diameter of the box, each half of which provided room for 12 slips. The glasses used in the same box were of different kinds; and as each pigmented slip was crossed by four glasses it gave a comparative result with regard to the effectiveness of those glasses when removed at any stage of the experiment. It will be seen from the above description that when removed, the slip showed bands, each one inch in length, of alternating faded and unfaded areas.

The second experiment confirmed the general results of the first experiment and gave greater precision to them. The injuriousness of direct sunlight, as compared with other methods of illumination, was amply demonstrated. In the case of a purple compolithographic ink, of the kind used in taking copies in typewriters, an easily perceptible fading was noticeable after an exposure of two hours, while the colour disappeared completely, so that the paper on which it had been painted became absolutely white, after a prolonged exposure. In crimson lake (water colour), magenta (alcoholic solution) and geranium lake (oil colour) fading was perceptible at 26½ hours, part of which were night hours. Carmine (water colour) and magenta (oil colour) showed fading after four days; crimson lake (oil colour) after 10 days; carmine (oil colour) after 21 days; gamboge (water colour) after 50 days, and alizarin crimson (water colour) after 78 days. It will be understood that these figures refer to the action of direct sunlight, and that in most cases the tinted glasses gave no pronounced differential result.

With regard to natural objects it must be noticed that the colours were less fugitive than those of most of the above pigments. The earliest periods at which fading was noticed were:—Front wings of the green oak-tortrix moth and hind wings of the scarlet tiger moth, 10 days; hind wings of the yellow underwing moth, 21 days; fur of tiger, 131 days; of a grey squirrel, 175 days; of brown horse and antelope, 1,485 days.

It must be explained, however, that the above figures are not to be accepted as the earliest dates at which fading might have been observed. Owing to interruptions caused by the War, there were long intervals during which time could not be spared for attending to the experiment; and the results recorded thus give a general idea of the relative fugitiveness of the colours used, without affording strictly comparable numerical *data*.

At the conclusion of the experiment, the slips bearing the more fugitive colours showed a striking appearance, the faded and unfaded areas being sharply contrasted bands, and in the most fugitive colours the exposed portions being absolutely bleached.

It is generally believed that while a water colour picture is liable to fade on exposure to light, an oil painting is improved by this treatment. My own experiments show that while a pigment used as a water colour fades more rapidly than the same pigment employed as an oil colour, all pigments are not completely protected by being made up with an oil medium. Geranium lake used in this way proved to be far more fugitive than most water colours.

In the exposures to diffused daylight it was found that some of the least fugitive colours remained unaffected even at the end of the experiment. This was the case with all the mammalian furs. The most fugitive colours were almost completely bleached; while the remainder were in a more or less faded condition, corresponding in amount with the order in which they were observed to fade in direct sunlight. Electric light (half Watt, 600 c.p.) showed a perceptible advantage over diffused daylight, in the fact that the absence of perceptible fading, at the end of the experiment, extended further down the scale of colours. This result is of great practical importance, as indicating that the use of this method of illumination in museums and picture galleries involves even less risk of deterioration of the objects exhibited than their exposure to ordinary daylight. The advantage of electric light is even greater than might at first appear, since even in galleries in which direct sunlight is nominally excluded there may be hours, at certain seasons in the year, when direct rays of the sun reach the objects exhibited.

My own experiments were too much interrupted to give a precise numerical result with regard to the relative injuriousness of different kinds of light; but it would be easy to repeat them in such a way as to obtain an accurate measure for each of the pigments used. It would probably be found that the figures would not be identical for all pigments; and my own observations show that the relative injuriousness is not the same at all stages of the fading. The most definite results were obtained by matching as closely as possible faded slips exposed to the three kinds of light. Under the conditions of the experiment, diffused daylight was about six times as injurious as electric light, while direct sunlight was from twenty to seventy times as injurious as diffused daylight. I attach little importance to these figures, and I must emphasise the

fact that my observations do not claim to have decided the exact relation.

In the above statements little account has been taken of the protection afforded by tinted glasses, and the actual figures given refer primarily to the parts of the slips covered merely by window glass; of which there were two layers, one the special strip used ins de the box and the other the glass lid which covered all the strips. The window glass was found to afford little if any protection, in accordance with what might be anticipated from its transmission curve for light. The effect of the tinted glasses was also in general agreement with the results of the first experiment; but the second experiment minimised rather than emphasised their utility. It should be explained that glass 38, which had proved the best in the first experiment, was discarded in the second, on the ground that its colour is so pronounced that there was no practical utility in ascertaining i.s behaviour further. With regard to the others, it was found that they showed a perceptible advantage, in some cases, at the beginning of the experiment, but that with prolonged exposures the advantage disappeared. In the majority of cases of maximum exposure, the fading under the tinted glasses was not less, or only slightly less, than that under uncoloured window glass, whatever form of illuminant had been used. The order of merit of the tinted glasses was, in general, 38 (greatest amount of protection), CB=AD, B=AL, ÇA.

In view of the great practical interest of the subject, it would be desirable to carry these experiments further. There are indications that a certain intensity or quality of light is required to initiate the process of fading, as is shown by the fact that certain pigments which fade in direct sunlight showed no perceptible change, even after four years, under the influence of diffused daylight or electric light. If a particular kind of light is capable of starting the process of fading, it appears that it is only a matter of time when the fading will be complete, and that the action of the light is, in fact, cumulative. This is further indicated by the behaviour of wood exposed to light. White pine slips become darkened, but their later history depends on the kind of light. In direct sunlight the initial darkening becomes modified in process of time, its colour becoming distinctly yellower instead of darker; an effect which may be dependent on the presence of resin in the wood. This may perhaps have some relation to the changes which occur in oil paintings during the lapse of time. But in slips of the same wood exposed either to diffused daylight or to electric light the yellowing did not occur; and this seems to suggest that these forms of light are not strong enough to inaugurate the change, whatever it may be, which causes the alteration of colour. Experiments with the media used in the preparation of oil colours might lead to interesting results. A prolonged experiment with pigments which are not fugitive is also to be recommended. If the fading can be shown to result from exposure to light of a particular intensity or quality, for any given pigment, it may prove that the slight amount of protection afforded by a suitable tinted glass may be sufficient to preserve the pigment in question completely from injury, under the conditions in which it is placed. If any fading at all takes place under the tinted glass, it will probably be found that it will become intensified as time goes on. Another obvious line of experiment is the use of light-filters known to transmit definite, restricted parts of the spectrum, with the object of ascertaining how far the rays of the violet end of the spectrum exceed the others in their capacity for inducing fading. The relative injuriousness of direct sunlight, diffused daylight and various forms of electric light, should be determined accurately. The method I have adopted in my second series of experiments could easily be applied to the solution of these and other questions by anyone who could find the necessary time.

DISCUSSION.

Dr. Alexander Scott, F.R.S., in opening the discussion, said the author was to be congratulated on having started on such an interesting research, and on having obtained such valuable results from it. Personally, he was particularly interested in the corroboration of the results which had been obtained by his late father in-law, Dr. Russell, and by Sir William Abney. Although the experiments of those investigators had been carried out almost forty years ago (they had been published about thirty-five years ago), they still seemed to stand. It was a very important fundamental point which Dr. Russell and Sir William Abney had laid down, and which, he thought, the author corroborated, namely, that light alone was not the agent, but that it was the moisture

and atmosphere which did the work. Light could be likened to a trigger of a gun. The moisture and oxygen represented the gun, but it was the light which set off the gun and made it capable of doing the mischief. The author mentioned that Sir William Abney had been inclined to think that it was ozone and not hydrogen peroxide which was the active agent. He, himself, could not believe that, and he would like to know what proof Sir William Abney gave in support of that contention. In his own opinion, it was the hydrogen peroxide which was the active agent rather than the ozone.

Another point which the author had touched upon was the rate of fading. He gathered that Sir Sidney was rather disappointed in not being able to get any sort of numerical relationship between the time and the fading. He (Dr. Scott) thought, however, that that was very easily explained. He thought the chemist would not expect to get such a relationship, because it had to be remembered that coloured bodies like magenta, for example, were very complicated organic bodies. Their closest relatives were almost colourless. Before arriving at the final stage of complete bleaching, a hundred stages might have to be gone through. If an object were exposed for an hour, the first minute produced a certain bleaching action which might diminish the colour enormously. Each succeeding minute would take off a little more of the colour, but the whole of the bleaching was done, probably, almost in the very first change. To get an absolutely colourless and completely bleached compound might take a long time, but a very small amount of chemical action might destroy 90 per cent. of the colour; in fact, in a material like magenta, he would say 95 per cent. of the colour would go. The very smallest change might make it a very slightly coloured compound. The step from a highly coloured compound to a colourless one was very small, and, therefore, it was hardly possible to conceive how any sort of numerical relationship between the change of colour and the time could be expected.

In the case of oil colours, they were practically sealed from atmosphere or from oxygen, and, therefore, one would expect them to remain much more permanent, and to be much less affected by light—which, as he had said, was not the active agent, but only the motive power. In the case of oil colours, however, there were other agencies at work, due, for instance, to the presence of turpentine, which tended to produce both hydrogen peroxide and ozone.

With regard to the colour of natural objects exhibited in the Natural History Museum, an interesting point had to be remembered. Those natural objects had run the gauntlet, before they arrived at the Museum, of tropical sunshine for many years, and had become, probably, very stable compounds. For instance, taking the colours in a tiger skin, the tiger had been in the jungle and his skin had been exposed to moisture, oxygen and brilliant sunshine for many years, and therefore the colours which remained were normally very stable. Before the skin came to the Museum it had had very prolonged exposure to sunshine, air and moisture.

With regard to leather, and the substances employed in it, he thought it was quite possible that the large number of modern agents which were used, such as chromium sulphate, might account very largely for the deterioration of the colours, and hence account for the discrepancy between the results of the Leather Committee and those of the author.

Mr. A. F. Kendrick (Department of Textiles, Victoria and Albert Museum) said the author had seemed a little inclined to apologise for what he had described as the somewhat superficial character of his experiments, but he could assure Sir Sidney that that was not the view that others would take of those experiments. The very fact of the author having spent seven years on the work meant that he was seven years in front of other people, and that was a long way. The problem, of course, was a scientific one, and it was necessary to look to scientific experts for its solution. Nevertheless, it was a very real problem to an Institution, such as the one with which he himself was connected, dealing with works of art and containing natural colours of the hair of animals, woods and so on. He might mention, also, that his own museum had artificial dyes, which, of themselves, formed very serious problems. He could quote one instance which was somewhat remarkable to him as a non-scientific person, namely, that if indigo was used as a water colour pigment it behaved exceedingly badly, but when it became a dye its action was admirable. As a dye there was no dye, he believed, faster than a good indigo dye; but as a water colour it seemed to disappear as soon as any other colour. He remembered that one of his very early experiences had been to see some dyes, which had been declared to be unfadeable, put out into the sunlight for several weeks, and he had seen those dyes fade away before his eyes. The pitiless march of the destructive forces, which nothing seemed to be able to stop, was almost a desperate problem to people who had charge of national collections where colour was concerned. He could not offer a solution to it. He would like to ask a few questions, some of which he thought could be decided from a common-sense point of view. First, with regard to blinds, the author stated that in the Natural History Museum he preferred a yellow-coloured blind to keep away sunlight. That had been an interesting statement to him, because it was a point on which he had come to the meeting to ask a question, namely, whether the colour of a translucent blind was of any importance in connection with the

subject. If one used a blind of a strong positive colour the objects could not then be properly seen. He would like to know whether a blind of an oatmeal or brownish drab colour, or any such colours, would be equally effective.

In that connection he might mention a small incident which had happened some months ago. He had been suddenly rung up by the editor of one of the London newspapers, asking whether the statement was true that the Museum, which had care of priceless treasures, the property of the public, nevertheless pulled down the blinds so that the public could not see them. He had been obliged to confess that approximately the statement was correct, but he had also tried to point out that it was no conspiracy against the public, but was done rather in their interests. He had also told the editor of the newspaper to get himself switched on to the Natural History Museum, where he would find the same practice existing, but where, no doubt, a very much clearer explanation would be forthcoming!

Another point was the question of curtains over articles. A good deal had been said to the effect that such curtains should be of some special colour, but he supposed that common sense came in in that connection: if a curtain was employed which was designed to keep out all light, surely it did not matter in the least what the colour was.

With regard to artificial light, the author's remarks were of the very greatest interest, but there was a difficulty about having artificial lighting in a Museum as a substitute for daylight at times when daylight was available. One reason was that even the best electric lights supplied a colour to the objects and destroyed some of their own colour. That brought him to the subject of the new light, about which so much was heard nowadays, which was called Sheringham daylight. Although he knew that Sheringham daylight was quite impossible for illuminating rooms in public galleries until it became very much cheaper, he would like to ask whether the reflection of that light on to special colours before it reached the object had any effect on the situation; that was, whether the enormous increase of the original power, though thus moderated, still had an increased deleterious effect. He would also like to enquire, in regard to the Sheringham daylight, whether it offered any solution towards destroying any slight injurious power that electric light might have by reflecting that light on to special colours—colours selected not from the point of view of reducing the colours to daylight, but reducing its fading properties. Was it possible that some line of research might be followed in that direction which would help in regard to artificial light?

With regard to the question of moonlight—or should he say moonshine?—he remembered talking to a friend in Paris who had there a very considerable responsibility in regard to the protection of objects from fading, and his friend had said to him, "You may say what you like about sunlight and its injurious effects, but it is nothing compared with the injurious effects caused by moonlight." He (Mr. Kendrick) had gone to a scientific friend in his perplexity and had asked him what he had to say about the point, and his friend had replied that although it might be true, and although there was a larger percentage of injurious rays in moonlight than there was in sunlight, the actual light was so infinitesimally small in comparison with sunlight that no one need have any fear on that point.

The author had said that if oxygen could be taken out of the air the effect might be minimised or reduced to nothing at all. Was it possible to substitute for the oxygen in a special case some other colourless gas which would not be injurious to the object; and, in the case of objects of very special value, could they be thus exposed to good ordinary light, or even sunlight, without being injured?

MR. NOEL HEATON considered that no one who had not undertaken researches of the kind described in the paper could realise their great difficulty and tediousness, and the enormous number of factors and sources of error which had to be considered to ensure reliable results. The practical result of the paper was to demonstrate that the Crookes glass which filtered out the actinic rays was practically useless as a protection against fading. It was evident, therefore, that the actinic rays were not, as one might imagine, the chief factor in the fading effect of sunlight.

It seemed from these experiments, in fact, that no colourless screen could be expected to have any protective value; the only glass that had any appreciable effect was the green which the author referred to as No. 38. The use of such a glass in windows or show cases was obviously quite impracticable.

The failure of the Crookes glass was rather surprising, and it shewed the value of checking any theories which one might form on the subject by the method of exposure tests adopted by the author. As apparently no colourless glass would produce the effect required, would it be possible to attack the subject in another way, by treating the objects with a protective chemical which would minimise the fading? It sounded an absurd suggestion to make, but it did not seem impossible.

He would rather like to challenge one statement made by the author, to the effect that oil protected pigment from fading. This effect was only relative. Certainly an oil medium would not serve to prevent fading in such fugitive colours as the author had experimented on, such as geranium lake, magenta and carmine. Nobody concerned with producing works of art

or paintings of any kind which he desired to pass down to posterity would ever dream of using any of those pigments.

With regard to the suggestion as to the carrying on of experiments on the fading of oil and varnishes, a great deal of work had been done in that direction. The mercury vapour lamp was used in most colour factories at the present time for this purpose, and generally the permanency of the pigments was registered according to the length of time they would stand exposure to that light.

THE CHAIRMAN said he had great pleasure in proposing a vote of thanks to the author for the lecture, which, he was sure, had been of the greatest interest to everybody. The patience which Sir Sidney had shown in conducting the experiments was, perhaps, explained by his knowledge that the ingenuity which he had shown was bound to lead to concrete results. He himself did not possess the mind of science, and throughout the lecture and the subsequent discussion he had been trying to think how the results attained could be best placed to the advantage of the community. It ought to be remembered that in Nature light was never isolated; in other words, that the effect of light in Nature derived actions, inter-actions, and re-actions from heat, from moisture, and, above all, from movement. There were whole groups of objects which did not themselves change colour, but, owing to the movement in the air, gradually acquired accretions of soot or dirt which in themselves gave a fresh coat of colour. Those were surface changes which connoted and involved ultimate colour changes; but where the true experiment was needed to be made, as the author had explained, was where the object was in a vacuum. Mercifully there was no vacuum in Nature. Nature would be very dull if unexpected and even paradoxical play were disallowed, and as there would never be a museum *in vacuo*, and as only a very small and most precious object in any museum could ever be put into a vacuum for the purposes of preservation, he supposed that process could not be looked upon as offering any real solution to the problem—he meant to the practical problem, not to the scientific problem—of how to preserve the specimens in museums or private collections from the ravages of light. However, the counter effects of heat had their merits. The darker the country and the more obscure the light of a country, the more drab and grey were the objects. There was no bright colour in Iceland. There was little colour in the great area which ran 3,000 miles across Siberia. Colour scarcely existed there. It was where the greatest enemy of colour existed, in Equatoria, for instance, that Nature provided its compensation by giving the most brilliant colours. What was the effect of darkness upon colour? It was commonly believed among dealers in pictures, and among people who had to look after pictures, especially miniatures, that a sojourn in a dark cellar was actually good for those objects; in other words, the darkness had a revivifying power. He did not think it was true; but it was the almost universal belief. He had come across a practical effect of darkness upon certain pigments quite recently. It was a very well-known case, and it was by no means isolated. Twenty-five years ago the pottery objects of the Han and Sung dynasties began to find their way to Europe. Many of them were in a fragmentary condition, having been recovered from tombs, or having got injured in the process of transport, and accordingly skilful Chinese forgers and restorers repaired the broken parts of those pieces of pottery. First of all Paris had taken that pottery up with great zeal, and there had been a great deal of money spent on it. The natural result was that a generation of forgers and sophisticators immediately appeared. Then it came to England, which redoubled their zeal. Then during the war people put their most valuable things into their cellars, and some of his friends had put their early Chinese pottery into their cellars. A very curious thing happened. One, two, or three years afterwards, when those things were brought out, the modern sophistications had changed colour. On looking at the figures—a camel or an ox, or some form of figure—one suddenly found that the two hind legs of an elephant, for instance, had become bright blue, or that the two front legs of a camel had become green, whereas, previously, they had only possessed the ordinary monochrome colour of the dynasties of Han and Sung. Yet those things had been exposed to ordinary daylight for fifteen years without any sign of discolouration having occurred. Of course, it might have been the dampness of the cellar that had caused the discoloration.

One question which ought to be settled was how far there was any justification in using the results of scientific investigations to preserve the colour of museum specimens, if only done at the cost of changing their aspect by introducing tinted glasses or coloured screens. Many years ago the Raphael cartoons at the South Kensington Museum had been placed in a fine gallery which was glazed with a nasty lemon-coloured glass, which gave one the feeling, when entering the room, of going into a tomb. It was admitted that Sir William Abney and his colleagues had been correct in saying if that glazing were introduced the discolouration of the cartoons would cease. But at what cost? He had never seen those cartoons, and nobody else had for the last 25 years, as they really existed. The actual appearance of those cartoons was being disfigured. For what object? In order that some day, some generation 100 or 500 years hence might see them, presumably without the glass,

and as Raphael had left them. Was it worth it? He did not think it was. He did not believe in vicarious virtue. He believed in using the good things of the earth as the Almighty had given them to us, and not in sacrificing too much to posterity.

He knew he was voicing the opinion of his hearers when he said that he hoped the author's investigations would continue. Never until that night had he realised how great and far-reaching were the disintegrating effects of light. He was only rejoiced to think that light had also happy and life-giving properties.

The vote of thanks was then put and carried unanimously.

THE AUTHOR, in reply, expressed his appreciation of the very kind terms in which the Chairman and other speakers had spoken of his paper. Dr. Scott had said he could not understand why Sir William Abney thought ozone and not hydrogen peroxide was the active agent. That, of course, was a chemical subject on which he (the author) could express no opinion. He had merely stated Sir William Abney's opinion, and he would give Dr. Scott the reference to it. Dr. Scott would find the paper printed in the 63rd Volume of the *Journal* of the Society. Sir William Abney was very precise and definite in what he stated there, and Dr. Scott would know how much importance it was necessary to attach to opinions expressed at that date.

Some remarks had been made to the effect that the colours of natural objects were ordinarily fast colours because many of the animals were exposed to tropical sun. He was not sure that it was known that even in our own latitude there was one conspicuous member of the mammalian class which was by no means proof against fading in the sunlight of the English day. He referred to the common red squirrel which faded to such an extent in the course of a year that it was at one time supposed that it was a different species from that found on the Continent. It was now known to be simply and solely the effect of fading during the life of the animal owing to its exposure to light. He could also quote one tropical animal whose colours, although exposed normally to a tropical sun, were by no means fast, and that was the tiger, as shown by his own experiments.

Mr. Kendrick had asked a question about the colour of blinds. He was afraid he could not give any very definite answer to that question. His own Institution used yellow blinds; it always had used yellow blinds. The colour was not offensive and did not alter too much the natural colour of the objects. That selection of yellow did not rest, however, on the result of any scientific investigation of the matter.

With regard to the colour of curtains, he quite agreed that if curtains were thick enough to cut off light altogether, there was no advantage whatever in one colour over another. A good many fabrics were not completely opaque, and then, of course, the question of colour might come into play.

He had no particular observations to make about the Sheringham daylight process of lighting, nor had he made any actual observations on the effect of moonlight.

The Chairman's remarks with regard to changes occurring in the dark were extremely interesting. He had no other explanation to suggest than that which the Chairman himself had given, namely, that the objects had been kept in a damp atmosphere.

With regard to the Chairman's remarks on the effect of tinted glass, he thought it would be quite possible to use some of the glasses on which he had experimented without producing any really very marked effect on the illumination of a gallery. That did not apply to glass No. 38, and, therefore, he had not thought it worth while to carry on further experiments with that glass in his second series. He had rejected it as a thing of no practical use. But any one of the intermediate glasses, for instance, No. 19, would be quite unobjectionable. If one looked through that glass in daylight one did not know that one was not looking through an ordinary window, so that it would be quite possible to use it if it could be demonstrated that it was really worth the trouble. But in this and other cases he was afraid that no large amount of protection would be produced.

The meeting then terminated.

NOTES ON BOOKS.

COURAGE IN COLOUR. By R. Goulburn Lovell, A.R.I.B.A., M.S.A. London: Charles Griffin & Co., Ltd. 6s. net.

Mr. Lovell is an ardent advocate of the use of colour in beautifying the home. It is, as he says, the simplest and cheapest means of carrying out this object; but many people are content with white woodwork, and grey or drab furnishings and wall coverings which are selected, not because they are beautiful, but because they are safe. To strike a bold note in colour requires a considerable amount of artistic taste and colour sense which, unfortunately, are not too common in this country, and without which the results are apt to be disastrous. The ordinary housewife is, therefore, probably wise in clinging to safe and unambitious attempts unless she can obtain sound guidance in her ventures. Such guidance is now afforded in "Courage in Colour." The author discusses the general principles on which colours may be associated so as to produce schemes of colouring

at once effective and harmonious, and he gives some useful hints as to the shades which may be best combined in rooms designed for various purposes. While, of course, the person blest with a colour sense can rely on his own instinct not to go far astray, the less fortunate individual will derive much confidence and help from the colour charts prepared by Mr. Lovell, and those who follow his advice in selecting shades according to his instructions will at least avoid disagreeable and clashing effects if they do not achieve artistic success.

We cordially commend "Courage in Colour" to the careful attention of all those who, while not confident of their own powers in selecting colours, are anxious to break away from the ordinary and commonplace in house decoration and furnishing.

ELECTRICITY IN AGRICULTURE. By Arthur H. Allen, M.I.E.E. London: Sir Isaac Pitman & Sons, Ltd. 2*s*. 6*d*. net.

In 1919, Dr. J. F. Crowley read a paper before the Royal Society of Arts, in which he described the use of electricity in agriculture, with special reference to Germany. The paper, which was published in the *Journals* of September 26th and October 3rd and 10th of that year, contained a great deal of information on the subject, and brought out very clearly the advantages which farmers may derive from the employment of electricity. Mr. Allen has now produced a handy little book (forming part of Pitman's Technical Primer Series) in which, after describing generally the sources of electric power and the means of distributing it, he discusses such questions as electric ploughing, haulage, pumping and irrigation, dairywork and electroculture. With regard to the last-named section, the author gives details of some experiments, with different crops in electrified areas. Potatoes grown in this way in 1914 showed an increase of 1 ton 3 cwt. per acre; while in 1915 the increase in the case of oats was 31 per cent. in the grain and 63 per cent. in the straw. In 1916 further experiments with oats showed an increase of 49 per cent. in the grain and 88 per cent. in the straw. The increased value of the crop was calculated at £6 7*s*. per acre, whilst the energy expended cost 11*s*. at 1*d*. per unit.

As to the Wolfryn process, in which seeds are electrified before sowing, the author states that large areas in Dorset were sown with seed treated in this way, and that the results were said by many farmers to be comparable with those already mentioned for electroculture. On the other hand, reports of the Director of the Experimental Station at Rothamsted, and by Messrs. Sutton & Sons, at Reading, on trials carried out in 1919, were unfavourable. In this connexion attention may be drawn to a paper read before the Agricultural Section of the British Association in 1919 by the late Dr. Charles Mercier, who stated: "Properly conducted, the electrification of seed never fails to produce an increase in a crop of corn. . . The increase in yield varies from four bushels to twenty or more bushels per acre; the average of a considerable number of trials is about ten bushels, or about 30 per cent."

In the face of these varying opinions it is to be hoped that authoritative experiments may be undertaken in order to settle the merits of the process one way or the other.

CORRESPONDENCE.

THE ECONOMY OF SMOKE ABATEMENT.

I listened with interest to the paper on the above subject by Mr. William B. Smith, reported in the *Journal* of December 22nd., and, had time permitted, should have joined in the discussion.

I came prepared to assert that smoke emission can be prevented, by consuming it, and I have been actively engaged for the past year in conjunction with the inventor of a system whereby smokeless combustion is secured and the 36% of oily "Hydro Carbons" quoted by the lecturer, as the amount given off in smoke, is now by this process converted into heat units and utilised to raise steam power, thus effecting great fuel saving.

I have already brought this under the notice of the London County Council and their Inspector has witnessed a demonstration of it; also the Medical Officer of Health for the County Borough in which the plant is in use reports as follows:—

"SMOKE ABATEMENT.—Adverting to the demonstration given on Friday the 6th instant by the Wyndham Smoke Consumer and Fuel Economiser Syndicate, I understand that owing to short notice members of the Public Health Committee were not able to attend, but that Mr. T. W. Cashman is prepared to give a further demonstration to the whole Council at any time the Council may decide.

"I quite understand that in connection with this invention, engineering considerations arise, but I need hardly remind the Council of the wonderful effect proved medically to result from sunlight, and the demonstration at Messrs. Whites' Yard, Abbey Mills, which I witnessed on the 6th instant, satisfied me of the possibility of ridding manufacturing towns of the smoke nuisance.

"Not only so, but the invention also lends itself to increased efficiency in dealing with the noxious effluvia arising from offensive trades.

"For these reasons I strongly recommend the Council to make an early appointment for seeing the proposed demonstration, as in my judgment the question is fraught with immense value to the public health and social comfort of the County Borough."

If any Fellows of the Society are interested in this recent contribution to the most important matter relating to Public Health and Fuel Economy existing in this country, I will gladly get further information for them from the Patentee, with whom I am in close touch daily.

F. W. CASHMAN, J.P.

MEETINGS OF THE SOCIETY.

ORDINARY MEETINGS.

Wednesday evenings, at 8 p.m.:—

JANUARY 17.—C. A. KLEIN, "Hygienic Methods in Painting—the damp Rubbing-down Process." THOMAS MORISON LEGGE, C.B.E., M.D., D.P.H., H.M. Medical Inspector of Factories, will preside.

JANUARY 24.—SIR WILLIAM HENRY BRAGG, K.B.E., M.A., D.Sc., F.R.S., Quain Professor of Physics, University of London, "The New Methods of Crystal Analysis, and their Bearing on Pure and Applied Science," (Trueman Wood Lecture). ALAN A. CAMPBELL SWINTON, F.R.S., late Chairman of the Council, will preside.

JANUARY 31.—THOMAS H. FAIRBROTHER M.Sc., F.I.C., and ARNOLD RENSHAW, M.D., D.P.H., "The relation between Chemical Constitution and Antiseptic Action in the Coal Tar Dyes." SIR HUMPHRY D. ROLLESTON, K.C.B., M.D., D.C.L., President of the Royal College of Physicians, will preside.

FEBRUARY 7.—CHARLES R. DARLING, F.Inst.P., A.R.C.Sc.I., "Electrical Resistance Furnaces and their Uses." SIR ROBERT A. HADFIELD, BT., D.Sc., F.R.S., will preside.

FEBRUARY 14.—W. J. REES, Lecturer on Refractories in the University of Sheffield, "Progress in the Manufacture of Refractories."

FEBRUARY 21.—C. AINSWORTH MITCHELL, M.A., F.I.C., "Handwriting and its value as Evidence." SIR RICHARD D. MUIR will preside.

FEBRUARY 28.—PROFESSOR W. E. S. TURNER, D.Sc., Head of Department of Glass Technology, The University, Sheffield, "Heat Resisting Glasses."

MARCH 7.—

MARCH 14.—SIR WILLIAM WARRENDER MACKENZIE, K.B.E., K.C., President of the Industrial Court, "Industrial Arbitration." LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, will preside.

INDIAN SECTION.

Friday afternoons at 4.30 o'clock.

JANUARY 19.—THE RT. HON. THE EARL OF RONALDSHAY, G.C.S.I., G.C.I.E., late Governor of Bengal, "A Clash of Ideals as a Source of Indian Unrest." The RT. HON. VISCOUNT PEEL, G.B.E., Secretary of State for India, will preside.

FEBRUARY 16.—J. T. MARTEN, I.C.S., M.A., Imperial Census Commissioner in India, "The Indian Census of 1921." SIR EDWARD A. GAIT, K.C.S.I., C.I.E., Member of the India Council, will preside.

JUNE 15.—SIR JOHN H. MARSHALL, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture).

DOMINIONS AND COLONIES AND INDIAN SECTIONS. (Joint Meetings).

MARCH 16.—Lieut.-Col. SIR LEONARD ROGERS, C.I.E., F.R.S., F.R.C.P., F.R.C.S., Physician and Lecturer, London School of Tropical Medicine, "Recent Advances towards the Solution of the Leprosy Problem."

APRIL 20.—SIR RICHARD A. S. REDMAYNE, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S., "The Base Metal Resources of the British Empire."

MAY 1.—L. GUY RADCLIFFE, M.Sc. (Tech.), F.I.C., "The Essential Oils of the British Empire."

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

HENRY P. STEVENS, M.A., Ph.D., F.I.C., "The Vulcanisation of Rubber." Three Lectures. February 5, 12, 19.

J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards, "Length Measurement." Three Lectures. March 5, 12, 19.

HOWARD LECTURES.

Monday evenings at 8 o'clock.

STANLEY S. COOK, "Recent Improvement in Steam Turbines." Three Lectures. April 30, May 7, 14.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, JANUARY 15 .. Geographical Society, New Bond Street, W., 8.30 p.m.

Victoria Institute, Central Hall, Westminster, S.W., 4.30 p.m. Rev. W. H. Isaacs, "Is Inspiration a Quality of Holy Scripture?"

Faraday Society, at the Chemical Society, Burlington House, Piccadilly, W., 8 p.m. (1) Mr. E. W. J. Mardles, "The Scattering of Light by Organosols and Gels of Cellulose Acetate." Study of the Reversible Sol to Gel Transition in Non-Aqueous Systems." I. The Chance of Viscosity with Time during Gelation. II. Viscosity Changes associated with the Gel to Sol Transition. "Changes of Volume and Refractive Index associated with (a) The Formation of Organosols & Gels (b) The Reversible Sol to Gel Transition. (2) Professor J. R. Partington and Mr. W. G. Shilling, "The Variation of the Specific Heat of Air with Temperature." (3) Professor A. W. Porter and Mr. J. J. Hedges, "The Law of Distribution of Particles in Colloidal Suspensions with Special Reference to Perrin's Investigations." Part II.

TUESDAY, JANUARY 16 .. Statistical Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.15 p.m. Dr. R. Dudfield, "The Registration of Disease."

Illuminating Engineering Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 8 p.m. Messrs. C. E. Greenslade and J. E. S. White, "The Need for Suitable Training in Illuminating Engineering."

Asiatic Society, 74, Grosvenor Street, W., 4.30 p.m. Miss E. G. Kemp, "Chinese Idealism in Temple and Bridge."

Transport, Institute of (Graduates Section), at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C., 5.30 p.m. Mr. H. C. Gunton, "The Employment of Transport in Relation to Post Office Operations."

(North-Western Section), The University, Manchester, 6 p.m. Mr. A. Davies, "Some Important Aspects of Railway Traffic Operation."

Royal Institution, Albemarle Street, W., 3 p.m. Professor F. G. Donnan, "Semi-Permeable Membranes and Colloid Chemistry." (Lecture I.)

Metals, Institute of (N.E. Coast Section), Armstrong College, Newcastle-on-Tyne, 7.30 p.m. Professor C. H. Desch, "Plastic Flow in Metals."

Photographic Society, 35, Russell Square, W.C., 7 p.m. Address by Mr. J. C. Dollman.

Anthropological Institute, 50, Great Russell Street, W.C., 8.15 p.m. Mr. F. W. H. Migeod, "The Bedde Group of Tribes of Northern Nigeria."

WEDNESDAY, JANUARY 17 .. Literature, Royal Society of, 2, Bloomsbury Square, W.C., 5.15.

Microscopical Society, 20, Hanover Square, W., 8 p.m. Annual Meeting. Presidential Address by Professor F. J. Cheshire, "The Petrological Microscope and its Optical Evolution."

Meteorological Society, 49, Cromwell Road, S.W., 7.30 p.m.

British Decorators, Institute of, Painter's Hall, Little Trinity Lane, E.C., 7.30 p.m. Mr. W. W. Davidson, "Stencils and their Use."

Chemistry, Institute of (Leeds Section), Queen's Hotel, Leeds, 7 p.m. (1) Mr. W. M. Mackey, "The Professional Aspects of Sampling." (2) Mr. G. Grindling, "Works Practice in Sampling."

Industrial League and Council, Caxton Hall, Westminster, S.W., 7.30 p.m. Sir E. J. P. Benn, "A Talk about Economics." *

Public Analysts, Society of (Joint Meeting with the Nottingham Section of the Society of Chemical Industry), University College, Nottingham, 7.15 p.m. Mr. A. C. Chapman, "The Detection and Determination of Small Quantities of Arsenic."

THURSDAY, JANUARY 18 .. Aeronautical Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.30 p.m. Major J. D. Rennie, "Flying Boats."

Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.

Linnean Society, Burlington House, Piccadilly, W., 5 p.m. (1) Captain G. H. Wilkins, "An account of the Shackleton-Rowlett Expedition in the 'Quest' to the Antarctic Regions." (2) Miss Helena Bandulska, "The Cuticular structure of certain Dicotyledonous and Coniferous leaves from the Middle Eocene Flora and Bournemouth." (3) Mr. W. R. Sherrin, "A Pocket Herbarium of the British Mosses."

Chemical Society, Burlington House, Piccadilly, W., 8 p.m.

Royal Institution, Albemarle Street, W 3 p.m. Hon. J. W. Fortescue, "The British Soldier and the Regimental Officer at the close of the Napoleonic War."

Dyers and Colourists, Society of (West Riding Section), Bradford, 7.15 p.m. Mr. D. Brownlie, "Steam Efficiency in the Dyeing and Allied Trades."

Mining and Metallurgy, Institution of, at the Geological Society, Burlington House, Piccadilly, W., 5.30 p.m.

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C., 6 p.m. Mr. G. H. Nelson, "Works Production."

Mechanical Engineers, Institution of (North-Western Branch), Memorial Hall, Albert Square, Manchester, 7.30 p.m. Mr. C. D. Andrew, "Machine Tools for Locomotives."

University of London, at the London Hospital Medical College, Turner Street, Mile End, E., 4.30 p.m. Mr. W. A. M. Smart, "The Mathematical Basis of Physiological Problems" (Lecture I.). at King's College, Strand, W.C., 5.30 p.m. Professor W. Barthold, "The Nomads of Central Asia." (Lecture I.) *

FRIDAY, JANUARY 19 .. Royal Institution, Albemarle Street, W., 9 p.m. Sir James Dewar, "Soap Films and Detectors—Stream Lines; Vortex Motion; and Sound."

Geologists Association, Architectural Library, University College, Gower Street, W., 7.30 p.m. Mr. G. Slater, "Some Aspects of Ice Phenomena."

Dyers and Colourists, Society of (Manchester Section), College of Technology, Manchester, 7.15 p.m. Professor E. Knecht and Mr. C. A. Hatton, "The Isolation of an Albuminous Substance from Raw Egyptian Cotton."

(Huddersfield Section), George Hotel, Huddersfield, 7.15 p.m.

Mechanical Engineers, Institution of, Storey's Gate, Westminster, S.W., 6 p.m. (1) Mr. Pendred, "The Problems of the Engine Indicator." (2) Professor F. W. Burstall, "A New Form of Optical Indicator." (3) Mr. W. G. Collins, "Micro-Indicator for High-Speed Engines." (4) Mr. H. Wood, "R.A.E. Electrical Indicator for High-Speed Internal Combustion Engines, and Gauge for Maximum Pressures."

Photographic Society (Pictorial Group), 35, Russell Square, W.C., 8 p.m. Mr. F. Judge, "The Claims and Prospects of the Pigment Processes"

SATURDAY, JANUARY 20 .. Royal Institution, Albemarle Street, W., 3 p.m. Sir Walford Davies, "Speech Rhythm in Vocal Music." (Lecture I.)

* Free Public Lectures.

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FRIDAY, JANUARY 19, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

NOTICES.

NEXT WEEK.

WEDNESDAY, JANUARY 24th, at 8 p.m. (Ordinary Meeting.) SIR WILLIAM HENRY BRAGG, K.B.E., M.A., D.Sc., F.R.S., Quain Professor of Physics, University of London, "The New Methods of Crystal Analysis, and their bearing on Pure and Applied Science" (Trueman Wood Lecture). ALAN A. CAMPBELL SWINTON, F.R.S., late Chairman of the Council, will preside.

Further particulars of the Society's meetings will be found at the end of this number.

BINDING COVERS FOR JOURNALS.

For the convenience of Fellows wishing to bind their annual volumes of the *Journal*, cloth covers can be supplied, post free, for 2*s.* each, on application to the Secretary.

DOMINIONS AND COLONIES AND INDIAN SECTIONS.

The Council have appointed Major H. Blake Taylor, M.Inst.C.E., late Indian Railway Department, a member of the Committees of the above sections.

MANN JUVENILE LECTURES.

The second of the two Juvenile Lectures by Mr. Charles R. Darling A.R.C.Sc.I., F.I.C., F.INST.P., on "The Spectrum, its Colours, Lines and Invisible Parts, and Some of its Industrial Applications" was delivered on Wednesday afternoon, Jan. 10th. Mr. Alan A. Campbell Swinton, F.R.S., (a Vice-President of the Society) presided.

Mr. Darling said that in the first lecture he dealt with the visible spectrum and explained how light waves were caused by the action of minute electrons—millions of which could be placed upon the head of a pin—which were flying about at enormous speeds of thousands of miles per second, being stopped or partly stopped. In red light there were 30,000 ripples to the inch, in blue light 60,000. There were other waves, and although the eye could not see them, they could be felt in the same way as the waves coming from a kettle of hot water, which were too long for us to see but could be readily felt. Light also produced electricity and became wireless waves. The very long light waves were turned into electricity in the wireless apparatus and worked the telephone receivers now being used for broadcasting. At the other end of the spectrum there were shorter waves beyond the violet; although these could not be seen directly, means could be employed to make them visible; there were bodies which had the property of taking in light, storing it up, and giving it out again. The effect that materials such as barium platino-cyanide had in lengthening out the spectrum was shown upon the screen. Invisible light is very much more active and intense on photographic plates than visible rays and will blacken a negative very quickly.

Mr. Darling then spoke of the ultra-violet rays and how Professor R. W. Wood of Baltimore, U.S.A. had discovered several kinds of glass which, while they would not let ordinary light through, being opaque, allowed these short invisible violet rays to go through quite easily. The meeting-room was then darkened and the effects of the invisible rays upon the finger nails, teeth and eyes of the audience very vividly demonstrated. The lecturer said that one of the most remarkable accomplishments during the Great War was the transportation of all the American troops without the loss of a single ship by submarines. The ships were able to keep together throughout the darkest night by making use of these invisible rays. On

one of the ships was fitted a structure similar to a lighthouse, the windows of which were made of thick glass like to the screen he had exhibited. The windows would not let ordinary light through them, but allowed all the rays beyond the violet, to pass, so that these rays were shining out in all directions although they could not be seen by the naked eye. Each ship in the convoy was fitted with one of the special screens and by this means they were all able to keep together on the blackest night and escape the submarines and yet no lights were shown on board the ships. The invisible rays were also used for signalling and sending messages at night. The beam of a search light could not be hidden, but one could send a beam of invisible light over a long distance which no one could see except those who received the message on one of the screens.

The more abruptly we stopped the electron the shorter the waves of light became, but in order to stop them quickly it was necessary to get rid of a lot of the air which acted like a brake. It was possible to pump the air out of a vessel but there were still electrons inside—in the glass and in the material placed in it. By removing the air they were able to get smaller waves than were obtained from ordinary light, and if they used a very powerful charge of electricity it sent the electrons down at a tremendous pace to the other end of the tube or vessel. They were stopped violently, with the result that we obtained a special kind of light wave, shorter than those we had considered previously. Tubes containing a shell, certain minerals (including willemite) and precious stones were then shown under this dazzling light. By continuing the pumping until sufficient air had been removed an entirely new class of ray was obtained —a wave so short that it was quite able to go through all kinds of things, except very thick layers of certain metals. These were called X rays. They were very short light waves, but in order to get them nearly all of the air had to be extracted from the tube and the electrons had to be brought to rest very quickly. These bulbs which were fitted with targets of tungsten—a metal which required great heat to melt it—gave out very tiny waves known as X rays. The action of the rays in penetrating a wooden box containing a key and some coins, and through a sheet of aluminium was demonstrated. The lecturer also described the remarkable properties of radium and exhibited a piece of the rare substance valued at £200. Radium he said, gave off even shorter and more penetrating waves than those obtained from the X ray bulb, and the action went on for years and years, without the aid of any apparatus. He exhibited a tube containing a specimen of kunzite, a variety of spodumene composed of silicate of aluminium and lithium—a mineral which has the property of absorbing radium rays and giving them off again when warmed to the heat of boiling water. Cinematographic views were then displayed showing various processes in the manufacture of tungsten and of X ray bulbs, and in the case of the latter the use of X rays in the detection of flaws in metals and their uses in various industries as well as in medicine, surgery and dentistry, were very graphically illustrated.

Mr. Darling concluded the lecture by saying that Dr. Mann, under whose bequest the Juvenile Lectures were now given, was particularly interested in the Spectrum, and that one of his objects in founding the lectures was to give young people an opportunity of seeing scientific experiments in the hope that they would learn to love science and become scientific workers. He hoped the experiments they had seen were in keeping with Dr. Mann's wishes. He said the success of the experiments was due to his assistant Mr. B. Abel. He wished to express his thanks to Messrs. Watson and Sons, Limited, for so kindly placing at his disposal the X ray apparatus and for the loan and demonstration of the film, and also his indebtedness to Mr. F. Harrison Glew for lending the radium used in the experiments.

On the motion of the Chairman a vote of thanks to the lecturer was carried by acclamation. This was acknowledged by Mr. Darling and the meeting terminated.

PROCEEDINGS OF THE SOCIETY.

INDIAN SECTION.

FRIDAY, 15TH DECEMBER, 1922.

SIR EDWARD R. HENRY, Bt., G.C.V.O., K.C.B., C.S.I., Inspector-General of Police, Bengal, 1891; Commissioner of Police in the Metropolis, 1903-18, in the Chair.

THE CHAIRMAN, in introducing the reader of the paper, said, as many present were aware, Commissioner Booth Tucker at one time

was a member of the Indian Civil Service. Having served in the same capacity himself he desired to say that he could imagine no better experience for becoming acquainted with the economic condition of the various areas in India. For the first few years of his official life the young Civil Servant lived amongst the people; he got to know them, and, above all, he got to like them. As a result he imbibed a strong affection for the people of India, who were a most lovable people. Early in his official life Commissioner Booth Tucker found he had a vocation, and was convinced that he could do more good to humanity by joining the Salvation Army. He had thrown himself heart and soul into the reclamation of the criminal tribes, and wonderful success had been achieved as a result of the efforts of his colleagues and himself.

The paper read was :—

THE CRIMINAL TRIBES OF INDIA.

By Frederick de L. Booth Tucker, I.C.S. retd.,
(Commissioner in the Salvation Army).

Crime in most countries is committed by individuals, in India usually by tribes, communities and gangs, who are highly organised and trained in it from childhood as a profession. The entire family and the relatives of an Indian criminal, including the women and children, are usually associated with him in the commission of crime. It is looked upon by these tribes very much as we regard the military profession, and is considered to be both honourable and lucrative.

There are now 18 settlements with a total criminal tribe population of 7,737 souls. These are distributed as follows :—

	Settlements.	Population.
Madras Presidency ..	5	3,635
United Provinces ..	8	2,176
Punjab	3	1,246
Bihar and Orissa .. (besides work among Pans).	1	348
Bengal Presidency ..	1	332
	Total	7,737

The following tribes are dealt with in these settlements—

Madras—Yerikulas, Veppur Parayas, and Korachas.

United Provinces—Doms, Bhatus, Beriyas, Sansiahs and Haburahs.

Punjab—Sansiahs.

Bihar and Orissa—Maghaya Doms and Pans.

Bengal—Karwal Nats.

Six of the settlements are mainly agricultural, but the settlers supplement their income by weaving, mat-making and other cottage industries. In two other settlements the employments are mainly industrial, but there is a considerable amount of agriculture. The rest of the settlements are almost entirely industrial.

The settlements are usually under the direct supervision of an experienced European officer and his wife, with a staff of Indian assistants, including expert foremen for the various industries.

As a rule the settlements do their own police work by means of picked settlers, and the district police seldom interfere with the internal affairs of the settlement. There is, however, usually a police post within convenient reach of every settlement, though requests for help rarely require to be made. The European Manager and his wife are the key to the situation, and are usually regarded by the entire Tribe as the "Man-bap" and chieftains of the clan.

To regularise the relations between the settlement managers and the district police and authorities, where there are several settlements, a special officer is usually appointed by the Local Government. In the United Provinces an experienced police officer is responsible for this work. In Madras a civilian supervises the working of the Act. In the Punjab a special department has been created.

An annual budget and statement of accounts is prepared by the heads of the Salvation Army, and submitted to the Financial Department for scrutiny and approval. While Government meets the cost of supervision, education and buildings, all profits from agriculture, or industries, apart from the settlers' shares, go towards making the settlements self-supporting. Where there are several settlements the losses on some may be partially covered by the profits on others.

The principal industries consist of weaving in cotton, wool and silk, mat-making, and needlework. In one settlement leather work is a speciality.

The Salvation Army undertakes the sale of all goods produced by the settlers, and usually tries to get orders in advance by means of travelling agents. There are also depots for the sale of goods in Simla,

Bareilly, Calcutta, Madras, and other centres, and from time to time special displays and sales of goods are organised in various centres. The last in Madras was opened by Lady Willingdon, and realised a turnover of about Rs. 4,000.

The organisation of Cottage Industries on a paying basis has been one of our most difficult tasks, as we have had to raise up and train our own expert foremen and forewomen for silk, handloom weaving, and needlework. It was several years before we could supply our needs. The existing weaving schools were engaged in training foremen for the great factories. They usually kept one or two handlooms as "curios" of an ancient and doomed industry, but regarded with amused incredulity the idea of giving an impetus to handloom weaving. To the Salvation Army belongs the credit of having produced the fastest and simplest handloom in the world, and of having created a revival of the industry itself.

We have always found the Local Governments, district and police authorities most ready to co-operate with us in minimising the difficulties which have arisen from time to time with the subordinate police.

The complete moral deliverance and change of life in hundreds, nay thousands, of these degraded and hopeless beings, saturated with crime, drunkenness, gambling and impurity, can only be realised when it is actually seen. The power of the Gospel to reform and revolutionise their lives must be seen to be believed. We have often been asked to undertake their moral and mental reformation without the aid of religion, but have invariably declined. And we can point to communities free from vice, free from crime, free from debauchery, whose whole lives were saturated with these evils, and who were the despair of their best friends. Their love for the Bible is extraordinary. "Put it under my head," said a dying criminal. "Let me rest my head upon its promises."

Origin of The Tribes.

Most of these tribes consist of Aborigines, who were once the owners of the land, but who have been dispossessed by successive invaders. They have, therefore, a real grievance in the background, and consider themselves justified in waging eternal war against the society which has wronged them.

Their Extent and Ramifications.

The whole of India may be said to be covered by these tribes with a perfect network of crime. The country is divided up into well-defined areas, where the various tribes operate. Their favourite haunts are on the borders of several states, provinces and districts, where they can baffle the police by flitting from one jurisdiction to another with extraordinary rapidity and skill.

One of their well-known principles is to grant immunity from depredation to any district which will afford them shelter and freedom from prosecution. The district authorities are enabled in such cases to report them as being crime-free, and to show an excellent record of immunity from crime, as compared with adjoining districts, where they are prosecuted and imprisoned. Moreover, a generous share of the plunder which they obtain from other districts finds its way to the subordinate police and officials.

Their Characteristics.

Different tribes follow different plans. Some are dangerous and resort freely to violence and even murder, while others may be termed sneak thieves. For instance, one tribe uses a sharp blade fastened to the forefinger, with which they cut the lobes of women's ears when asleep, and rob them of their earrings. Others are expert burglars.

One dangerous gang made a speciality of robbing and murdering moneylenders, as they went from village to village after the harvest collecting their debts. The bodies were thrown into wells. One of the gang was at last captured, and turned King's evidence against the rest, who were all captured and sentenced. The released thief stole two valuable horses from the police officer concerned in the capture of the gang, and wrote him the following letter :—

> "You are a very clever Sahib. You have captured the——gang. Now tell me who has stolen your horses, and where they have gone.
>
> "Signed, The Thief."

There is a grim sense of humour among these tribes, and they are never better pleased than when they have outwitted the police.

Their Numbers.

The numbers of the criminal tribes have been variously estimated according to the

inclusion or exclusion of certain semi-criminal tribes.

For instance, there are some tribes which pursue the ordinary avocations of agriculture and industry, and at the same time maintain a secret force of robbers for which the rest of the tribe act as receivers and distributors or consumers of the stolen goods. Whenever any of the gang are caught, and sent to prison, their substitutes are at once chosen and sent into the field.

In the Punjab alone, the registered criminals number, with their families, no less than 130,000. In the United Provinces, their number is still greater; while all Provinces of British India have quotas varying in number according to the activity, or otherwise, of the authorities in enforcing the provisions of the Criminal Tribes' Act.

Government Plans for Dealing with the Problem.

It is scarcely necessary to say that the problem has long engaged the careful attention of the British Government. A special Act has been passed for the registration and control of Criminal Tribes. Extensive efforts have at the same time been made for their reformation by gifts of land and cattle. Three great difficulties have been encountered.

1.—Crime is a paying proposition.

2.—It is such an easy way of getting a living that the tribes prefer it to hard labour.

3.—The subordinate police and village officials have been accustomed for many generations to obtain a generous share of the plunder and to protect the perpetrators from discovery and punishment.

Salvation Army Efforts to Reform the Tribes.

About fourteen years ago, Sir John Hewett, the Lieutenant-Governor of the United Provinces, invited the Salvation Army to attempt the reformation of these tribes. Since then the Governments of the Punjab, Bengal, Bihar and Orissa, and Madras have similarly employed our agency, with the result that we have now some seven to 8,000 men, women, and children committed to our charge. Our efforts have been admitted by the various Governments to be remarkably successful, and while the problem is by no means solved, the lines have been greatly improved along which a final solution may be regarded as both possible and probable.

The main principles we have followed, with the hearty approval and co-operation of Government, have been the following:—

1.—We have roughly classified the tribesmen as

a. Incorrigibles or *Won't-be-goods*, and
b. Would-be-goods.

2. We have protected the Would-be-goods from their natural enemies; that is, from those who seek to force them to commit crime in order to share the plunder.

3. We have sought radically to reform the *character* of the people committed to our charge, and not merely their circumstances. In this our success has been most gratifying.

4. We have introduced, with Government approval, an entire change in the registration of these people. Instead of a single register in which all were recorded as *badmashes* or criminals, and even the children were automatically so registered on reaching adolescence, we have introduced three registers:—

a. A register for badmashes.
b. A register for nekmashes (good characters), a new title which we have coined.
c. A register for crime-free adolescents.

Furthermore, the nekmash has been supplied with an official certificate which has rendered him immune from the interference of the police.

5. We have made a speciality of reforming the women and children, and of thereby strengthening our hold upon the men. When the husband has been sent to prison for some crime, we have looked after his wife and children, instead of leaving her to the dreadful alternative of marrying another criminal for her support, resulting usually in a family feud when the original husband was released.

6. We have found remunerative work for all, carefully selecting suitable industries, acceptable to the people, and undertaking to dispose of their produce. In the case of both industry and agriculture, we have provided skilled supervision. The forms of employment which have been most acceptable have been weaving, silk and silkworms, mat-making and similar industries requiring delicacy of touch and skill. In short, we chose forms of work which would increase

rather than diminish their self respect. "We are not coolies!" they would often exclaim, when they came to us. We agreed with them and found it easier to make them into skilled artisans.

Our Difficulties.

1.—*The Problem of their Support.*

This has been a serious problem. Here were thousands of men and women who had followed for generations the lucrative profession of crime. To persuade them to work, and to work hard, with a prospect of earning perhaps Rs. 5 to Rs. 10 a month per family, has been no easy task. That we should have succeeded in making most of our settlements both crime-free and self-supporting, while the families are mostly well-fed, well-clothed, honest and prosperous, appears to be highly satisfactory.

2.—*The Danger of Settlements Becoming Rat-traps.*

One of our greatest difficulties has been the fear lest the police should use the settlements as rat-traps. It has been difficult on the one hand, to eradicate this fear from the minds of our settlers, and on the other, to prevent the police from so using them. In the United Provinces both Sir John Hewett and Lord Meston provided a very sympathetic and energetic Police Superintendent to act as go-between with the Government and the police. The results were excellent, until we were raided by the police from an adjoining Province. For some time a panic prevailed, and we received a very serious setback.

3.—*Changes of Policy.*

Each British Province has been a law to itself. While some have enforced the provisions of the Criminal Tribes' Act, others have jibbed at the expense, and have either refused to operate it, or done so only partially. Worse than this have been the frequent changes of policy on the part of changing officials in the Provinces where settlements were located. The Indian States have mostly declined to take up the question on the score of expense. The execution of the law being thus more or less optional, or perhaps I should say experimental, the tribes have been able to escape from the jurisdiction of one territory where it was in operation to another where it was neglected.

4.—*Settlements as Raiding Centres.*

There is an obvious danger that the settlements may be used by unreformed members of the tribes as raiding centres, and also that unrestricted criminals, in no way connected with the settlements, may seek to throw the blame of their crimes on to the settlements.

Suggestions for Future Improvements in Dealing with the Tribes.

1.—*The Won't-be-Goods, or Incorrigibles.*

These are now well known to the authorities and to us. Hence, we have strongly urged Government to locate them *with their families* in self-supporting settlements on islands, where raiding would be impossible, and where they would be compelled to earn an honest living. They would be owners of their lands and houses, and accompanied by their families. So there would be no hardship. Numerous islands with excellent harbours are available for the purpose.

2.—*Annual Conference.*

We have further suggested that the Government of India should hold an annual conference, at which all Provinces and States should be represented, together with persons actually engaged in the work. Papers would be read, and plans laid for enforcing the Act, for its universal application, and for improving the settlements and settlers.

3.—*A Special Criminal Tribes Department for all India.*

I have called the attention of Government to the admirable system organised by the Government of the United States for dealing with the very similar problem of the Red Indian population. These number about 350,000. A Federal Department has been created for their supervision, control, protection and reformation. They have their own budget for income and expenditure. As a result, instead of being a turbulent, marauding, dangerous community, requiring a strong military and police force to limit their depredations, involving a costly series of petty wars, they have quickly settled down as a well-behaved and prosperous community.

If the above plans were put into effect, and the criminal tribes of India were placed under the sympathetic supervision of honest organisations, interested in their reformation

and capable of protecting them from those who at present prey upon their weaknesses, I believe that these tribes could be redeemed and turned into law-abiding, prosperous communities in a comparatively short space of time, and at a far less cost than is now involved in their ordinary control and punishment.

[The paper was illustrated by numerous lantern slides, which were described by Mrs. Booth Tucker.]

DISCUSSION.

THE CHAIRMAN (SIR EDWARD R. HENRY), in opening the discussion, gave a short account of the conditions under which the earliest criminal settlement in India was established. The first district to which he was appointed, in 1882, was the most north-westerly district in Bengal, which had as its frontier the Nepal Terai. It was probably one of the worst malarial tracts to be found anywhere, lying as it did between the British boundary and the lowest ridges of the Himalayas. The cultivators in the district were, however, practically immune from malarial fever; they were known as Auliyas, *i.e.*, immune from the terrible malarial fever *Aul*; they cultivated the land and eked out a precarious living. In addition there were a number of Maghayas, who lived in encampments, the children often being born in the fields. They never had a roof over their heads, except when they were in jail. It seemed to him to be almost a blot upon the British Administration that any class of people should be living under such desperate conditions, and he came to the conclusion that if something could be done to improve them it would be a work of humanity. The people in the district were terrorised by the Maghayas, who, Sir Herbert Risley said in his book, could always elude pursuit, being so fleet of foot that no man on horseback could overtake them. Personally, he did not believe that statement; he thought a man on a good polo pony would overtake anyone on foot. They had a sort of bird-like instinct; on the darkest night they would make for a distant objective, and be sure of getting safely home again. The villagers were always suffering from raids, and he thought a trial should be made to settle the people. He came to the conclusion that if he reported it to the Government they would only ask for further information, and he, therefore, went to some of the leading people, who promised him help in the way of land, money, grain, and ploughing bullocks. He knew that a few months afterwards there was to be a big jail delivery of prisoners belonging to the Maghayas, and he set to work to build a number of houses. He then went to the women waiting outside the jail for their released men and told them that, provided their men when they came out of prison would comply with certain requirements in regard to discipline, such as not absenting themselves at night, shelter, land, grain and money would be given them. The women promised to help. The plan was put into operation and was a great success. After the work had been going on for a year he reported to the Government, who very willingly said that they would give him the financial assistance he required; in September, 1885, a resolution by the Government, stated they were thoroughly satisfied with the success of the settlement, which comprised 170 adults and 90 children, and was self-supporting. Soon after he was removed to a distant part of the province and his connexion with the criminal settlement ceased; it was self-supporting when he left it, and it was still in existence. The success achieved by the Salvation Army in their criminal settlements was even more remarkable than Commissioner Booth Tucker had stated, because the work came under the Criminal Tribes Act of 1911, which appeared to him to be the most extraordinary Act that was ever put upon the Statute Book. Section 3 of that Act gave the Local Government power to declare that any class, tribe, caste, or gang of people were criminal. A whole tribe could be classed as criminal simply on the *ipse dixit* of the Local Government. It seemed to him to be very hard indeed that, even supposing a certain proportion of a tribe were criminal, the whole tribe should be registered as a criminal tribe. The effect was that if a man committed a non-bailable offence, like burglary, for the second time, because he belonged to a registered tribe he was liable to seven years' transportation; and if he committed the offence for the third time he was liable to transportation for life, in addition to any other punishment provided by the Penal Code and there were many other penal consequences. The Code of Draco was not in it with this Act, and he could not understand how it ever was passed. The Indian Jails Committee, 1920-21, commented severely upon the Act, and referred to the enormous power it put into the hands of subordinate officers. Such power was bound to be abused and it made the settlement of criminal tribes extraordinarily difficult. The more power the police were given the less chance they had of being popular. In his opinion the great thing to do was to give the police limited powers and to see that they exercised them in such a way as not to commit injustice. If a man committed a crime it should be simple enough to get a conviction, and now that a system of fixing identity existed, so that it could never be confused, the police ought to depend upon that power and that power only. It was stated in the Report of the Indian Jails Committee that in one of the settlements only 130 men out of 700 had ever been convicted of crime, so that 80 per cent. of the males who

had been placed in a criminal settlement for life had not been convicted of crime at all. An important consideration in determining settlement was whether the economic conditions were such as would enable the settlers to become self-supporting. In places where the settlement was near mills or public works, other agencies could probably make the settlement a success; but the conditions were much more difficult in agricultural settlements, which required the sustained efforts of the Salvation Army to make them a continued success. It was not fair to the Salvation Army or to other agencies which undertook settlements that they should do so where the conditions were not favourable. If there were to be agricultural settlements the land ought to be fairly good; facilities for irrigation ought to exist, and the country ought not to be unhealthy. He thought those present would arrive at the conclusion after hearing the paper that settlements under the Salvation Army under reasonable conditions could be a tremendous success, but the Government had made the meshes of their net a great deal too small. As he had said, it was not right or reasonable that whole castes should be registered as criminal because a certain number of people belonging to that caste had criminal proclivities. If the meshes of the net were made much bigger there would be less discontent arising from the sense of unjust incarceration, the settlement would gradually expand in numbers, become more and more self-supporting, and the outcasts of society dealt with get a chance of leading a decent life. The object was the gradual absorption of the settlers into the community, and unless that aim was kept in view the Settlement of Criminal Tribes had no valuable meaning.

Sir John Prescott Hewett, G.C.S.I., K.B.E., C.I.E., M.P., said those present were greatly indebted to Commissioner Booth Tucker and his wife for the most interesting account they had given of a wonderful experiment, which, to his mind, bade fair to have more effect in the reduction in crime in India than such dramatic efforts as had been made to suppress thuggi or the ordinary, though less showy, work of the police administration. When he first went out to India the earliest Criminal Tribes Act had been in force for three or four years, and the first sub-divisional charge he held was in the Agra District, bordered by the States of Dholpur and Bharatpur. That tract had been the scene of a great deal of trouble in the Mutiny, and the people had never been disarmed until the Arms Act of 1878 was, in his time, brought into operation. The place was a regular Tom Tiddler's ground for criminal tribes. At that time the criminal tribes were completely under the control of those whom they regarded as their hereditary enemies, the police, and not much had been effected in the way of reforming them. As he served for 15 years in the Home Department, he had the opportunity of reading all the reports from different parts of India with regard to the operations of the Criminal Tribes Act; and before he left he came to the conclusion that when people, who not only had criminal instincts but were also devoid of elementary ideas of decency and morality, were being dealt with, official action was of no use whatever. It was necessary to employ some organisation of religious zealots with infinite patience and unflagging enthusiasm. When Commissioner Booth Tucker came to him, at the suggestion of Mr. Tweedy, then Commissioner of Rohilkhand, and suggested that he should undertake the management of the criminal tribes in certain parts of the United Provinces he (Sir John Hewett) did not take much time to realise that that was exactly the sort of agency to whose care they should be entrusted. That was the origin, as Commissioner Booth Tucker had explained, of the settlements. Very shortly after certain tribes in the United Provinces were made over to the Salvation Army, some Hindu members of the Local Council raised a debate on the question. They contended that it was unfair to employ a Christian agency in preference to Hindu agencies. But these opponents were in a minority. The Indian members, with few exceptions, were firmly of opinion that no Hindu or Indian agency was so fit to have control of the criminal tribes as the Salvation Army. Every Mohammedan member voted in favour of the Government's decision, and a Brahmin, now one of the leading non-co-operators, made a speech on the same side. The majority was something over 40 to about seven against. Commisioner Booth Tucker had shown the enormous success which had been achieved in inducing the criminal tribes to take up industrial pursuits properly. He included agriculture in industrial pursuits, because one of the impressions which must be drawn from the reports on previous efforts was that all the agricultural settlements failed because the work was undertaken in a desultory sort of way, and there was really no sanction to enforce work by the criminal tribes. The presence in each Salvation Army settlement of a European and his wife created or revived a moral sense among the tribes, and inspired them with a desire to do their best in order to repay the efforts of those who were spending their lives in reclaiming them. This, as Commissioner Booth Tucker said, was the real key of the situation. A remarkable achievement was getting the better part of the settlement to act as police officers. That got rid of the interference which at one time tended to prevent the success of the undertaking; because the ordinary police were, as a rule, if left to themselves, only too anxious to inflict pinpricks. The Salvation Army had succeeded in establishing so good a police in the settlement that the regular police did not interfere with them. Commissioner

Booth Tucker had made a certain number of proposals for the improvement of the existing arrangements, and, personally, he thought it would be well if the Government considered them all. Difficulties lay ahead, but he believed they would all be overcome. The subject was an enormous one, and the fringe had only just been touched. He was, however, convinced that in time the Salvation Army would succeed in the object it had in view, namely, the absorption of the criminal tribes into the ordinary population. When that had been done, Commissioner Booth Tucker and those who worked with him, and those who in future would follow him, would have combined to achieve one of the greatest moral reformations that the world had ever seen.

Sir Thomas J. Bennett, C.I.E., M.P., in proposing a vote of thanks to the author for his excellent paper, to Mrs. Booth Tucker for her admirable description of the lantern slides, and to Sir Edward Henry for presiding, said that when he first went to India, in 1884, the Salvation Army was newly established there, and he had very distinct recollections of the spirit in which the people among whom he moved at that time regarded it. It was a spirit of anything but reverence and respect. He remembered too that at that time Commissioner Booth Tucker had recently resigned from the Civil Service, and the prevailing opinion was that he was a very good and very well-meaning person, but very eccentric, and nobody thought he would ever achieve much success. He jumped almost from a recollection of that kind to the fact mentioned by Mrs. Booth Tucker, that the Government of Bombay had asked the eccentric and romantic Salvation Army to take over the eminently practical work of managing the beggars of Bombay. Sir John Hewett had given a most important pronouncement of an authoritative nature based upon his knowledge and experience, that the reclamation of the criminal tribes of India was work which could not efficiently be undertaken by official agencies, but should be handed over to religious and moral agencies of the kind so worthily represented by the reader of the paper on the present occasion. That was an important fact, and it should be widely known, because one could almost see in it the basis, if not of a new policy, at all events an encouragement to continue on the widest possible scale that method of dealing with the criminal tribes which the Salvation Army had undertaken with such splendid results.

Mr. G. A. Tweedy said that in 1908 the minds of the authorities were seriously exercised on the subject of the criminal tribes, and when he was Commissioner of Rohilkhand, Commissioner and Mrs. Booth Tucker visited Bareilly, and gave a lecture there. The idea then occurred to him that there existed in the Salvation Army an agency for tackling the problem of the criminal tribes. He spoke to Commissioner and Mrs. Booth Tucker after the lecture, and they seemed to think the idea a good one. He subsequently mentioned the matter to Sir John Hewett, who eventually gave Commissioner Booth Tucker an interview, the result of which was the great work which had been described in the paper. There was no part of his Indian work that he cherished more than the thought that he was able in some small way to help on the splendid work of the Salvation Army.

Lord Pentland, G.C.S.I., G.C.I.E., said he had been delighted, as an old Governor of Madras, not only to hear in the course of the paper a reference to Stuartpuram, but to see a photograph of it on the screen. His old friend and colleague, Sir Harold Stuart, after whom the settlement was named, had asked him to express his regret that he was unfortunately prevented from attending the meeting that afternoon. He desired to say, on his own behalf, that he agreed with all Sir John Hewett had said in regard to the importance of the work done in India in the sphere to which the author had referred, and he did not think the Government could be too grateful to the Salvation Army for the admirable work it was doing in that and other respects. As years went on he was sure it would be found that voluntary work of that and other kinds would become more and more valuable to India and to this country.

Mr. Bhupendra Nath Basu, in seconding the motion, said that to him, and to other Indians like himself, the pictures which had been thrown on the screen of English Salvationists clothed in Indian costumes conveyed a deep meaning and significance. It was true that the Salvation Army had not been able to divest itself of the hideous head-dress which European women wore, and which they thought adorned and beautified their features; but apart from that blemish, which probably was unavoidable having regard to the heat which prevailed in India, they had brought themselves much more closely to the hearts of the people than any other religious body from the West had been able to do. Personally, he was justly proud that he inherited a culture and a civilisation which was probably one of the oldest in the world, but at the same time he did not overlook the fact that this civilisation and culture had very serious blots upon it. One of those blots was that large masses of men and women had been treated as beyond the pale of society, as "untouchable" and "unapproachable." That had been one of the greatest stigmas on Indian civilisation, and, therefore, as a Hindu, he welcomed and appreciated the efforts which the men and women of the Salvation Army had put forward in India to reclaim those who, from want of sympathy, or knowledge, or

understanding on the part of the higher classes in India had been relegated to the position in which they were at the present moment. He was not ashamed to confess that because it must be realised that most civilisations had their drawbacks; and it was because his own civilisation had that great drawback that he welcomed the help which the Salvation Army rendered to it. He also desired to say that Indians did not resent really religiously-minded men and women working among them in the spirit in which they ought to work. He did not think he would be saying anything wrong when he said that, in spite of the Christianity which had prevailed in the West for two thousand years, it was time that this country should be re-Christianised and that Europe should be saved, not from Christianity, but from the Machiavellian doctrines which were prevailing in the chancelleries of Europe. He, therefore, all the more appreciated the saving of the people of India from the pernicious doctrines which their ancestors promulgated, by which large masses of men and women had been placed in the position to which he had referred. Co-operation was required in India of all men and women of goodwill, just as the co-operation of all men and women of goodwill was also required to rehabilitate Europe. In seconding the motion, he could only say that the thanks of Indians were due to Commissioner and Mrs. Booth Tucker and other workers of their stamp for the good they were doing in India.

The motion was carried unanimously, and the meeting terminated.

NOTES ON BOOKS.

THE GRAPHIC ARTS. By Joseph Pennell. Chicago: The University of Chicago Press.

This volume contains the Scammon Lectures delivered by Mr. Pennell at the Chicago Art Institute in 1920. Before (unfortunately for us) he decided to leave this country for New York, Mr. Pennell was very well known at the Royal Society of Arts, where he frequently spoke and lectured to an audience that always appreciated his forceful originality of expression as well as his artistic taste and power. It is some consolation for the loss of his presence here to know that he is carrying on his lecturing work in America. The present series of lectures is as good as anything of the kind that he has done. He has an enormous wealth of material relating to woodcutting and wood-engraving, etching and lithography, and he has been able to include about 150 illustrations in this volume. It goes without saying that these are admirably selected. Some of them are beautiful, all are interesting. One of the most remarkable is an etching by Whistler of a doorway in Venice. This is an extraordinary piece of work, at once strong and delicate, and the different qualities of the materials represented—iron-work, stone and water—are expressed with amazing skill. As Mr. Pennell says, "Whistler says he could not draw architecture. I don't know who could have drawn this Venetian house better."

Scarcely less beautiful is a lithograph of a doorway of Rouen Cathedral by the author himself, while another illustration showing him at work on a lithograph is of unusual interest and goes far to explain the charm of his lectures. He knows as well as anyone every step in the process, and he works as hard and as eagerly at the so-called mechanical side as at the draughtsmanship of his work. What he says is therefore practical in the first degree, and his lectures should prove a source of inspiration to the students to whom they are addressed.

OBITUARY.

ALFRED EDWARD CAREY, M.Inst.C.E., F.C.S. —The death took place of Mr. Alfred Edward Carey, on December 30th. He was born in 1852, and had been in practice as a Consulting Engineer for over forty years. He was Resident Engineer for the construction of Newhaven Harbour Works, and for some years he specialised in advising firms engaged in the Portland cement industry. He was appointed Engineer-in-Chief for La Guaira Harbour Works, Venezuela, and was responsible for the Fishery Harbour at Southwold. His firm, Messrs. Carey & Latham, MM.Inst.C.E., have since the war been responsible for the execution of public works of considerable magnitude—amongst others, the most modern deep-water quay in the River Thames, the riverside accommodation of the Empire Paper Mills, Ltd., Greenhithe, and extensive coast defence works for the County of Somerset.

Mr. Carey was the author of several notable technical books, including "Tidal Lands," written in conjunction with Professor F. W. Oliver; "The Making of High Roads," and many other papers contributed to various learned societies, dealing principally with marine works. He also wrote a number of novels, and he possessed a very fine collection of prehistoric implements.

He was elected a Fellow of the Royal Society in 1898. In 1907 he read a paper here on "The Protection of Sea Shores from Erosion," for which he received a silver medal. He also contributed a number of letters to the *Journal* from time to time.

PIG HUSBANDRY IN SCOTLAND.

During the year 1922 pig-breeding has again advanced considerably in Scotland. To such an extent, indeed, is this the case that some of the pure-breeds are now represented by a great

number of herds. Curiously enough, it has been shown that, out of the 13 pure breeds of pigs which are recognised in the British Isles, the Large Black breed is best suited to the climatic conditions of Scotland. As a consequence, the number of herds has grown, within the last two or three years, to something like 100; and these Large Blacks are being utilised for crossing with other pigs, with a view to the production of the typical bacon pig which is so much desired. The prepotency of the Large Black sire is such that excellent crosses are derived from a Large Black and a Large White, or a Large Black and a Middle White; and there are many other crosses which also give satisfactory results. In curious contrast to the wonderful progress which has taken place in Scotland in the development of this particular breed, it may be mentioned that another pure breed—namely, the Wessex Saddleback, which has been much extolled in the Eastern and Southern Counties of England, is represented in Scotland only by one registered breeder.

The pig population in Scotland has shown a wonderful increase during 1922, and the latest figures available would show that, as compared with the previous year, the number of pigs in the country has increased by 4888. In England and Wales, on the other hand, there was a marked decrease in 1922 as compared with 1921, the total figures being 208,800, and this notwithstanding all the activity which has been exhibited by the various pure-breed societies. The pure breeds are, of course, essential for the maintenance of the high standard of stock; and it seems curious that there should be such a large increase in the membership of the pure-breed societies, but that the net result is a reduction in the total pig population. Undoubtedly this is due to a large extent, as has been frequently pointed out, to the absence of a steady market for bacon pigs, which all pig breeders want, and which can be supplied by the establishment of bacon factories in suitable centres. The fluctuations which take place in weekly markets, and in the prices offered by dealers, are so great that there is very little inducement to pig breeders of ordinary cross-bred stock to breed for sale in this particular way. Hence the demand for the establishment of bacon factories throughout the country.

The increase in pig population in Scotland is primarily due to the good work carried on by the Scottish National Association of Pig Breeders, which has now taken a firm hold throughout the country, and whose membership is composed of the principal pig breeders, pedigree and otherwise, throughout Scotland. This Association came into existence at a time when pig breeding in Scotland was in a very unsatisfactory condition; and in two short years it has, by its influence, altered the whole outlook in connection with the pig breeding industry. The bad, unprofitable days of stye feeding of pigs have practically disappeared from Scotland: and the great majority of the herds are now allowed freedom to roam about in paddocks or in woods, where they get plenty of healthy exercise and a certain amount of food in addition to the regular diet given to them.

On a great many estates pig breeding has been adopted with a view to the uprooting of bracken; and this particular use of the pig has been demonstrated as offering a remedy for bracken-infested areas of a very simple and profitable kind.

The character of the feeding also of herds of pigs is rapidly undergoing a change, as it has been shown that feeding on wet food is not at all so profitable as a properly constructed diet of dry food fed to pigs in automatic hoppers. In conjunction with this method of dry feeding, pig breeders during the past year have found that it is sufficient to put the dry feeders in the open air paddocks along with a plentiful supply of water to ensure rapid maturity and profitable returns. The total equipment, therefore, under this new system of housing pigs is a very simple one. First of all, paddocks of, say, one and a half to two acres in extent, are enclosed by strong wire netting; one or two wooden shelters of the simplest character are provided, and a sufficient number of dry feeders and water troughs to provide food for the number of pigs enclosed. By this system it is contended, and so far has been amply demonstrated, that early maturity is obtained and costly labour is minimised.

The principal object of all pig breeding is the production of bacon, hams, and pig products; and attention cannot be too often directed to the fact that the principal sources of such supplies are overseas. We imported last year bacon, hams and fresh pork to the value of £55,000,000, and if the other pig products were added this figure would be enormously greater. In contrast with this it may be estimated that the value of bacon, hams, sausages, lard, and all other products derived from the pig, and handled in factories in Great Britain, does not exceed £15,000,000 sterling; so that we are apparently dependent on overseas countries for products which, there is every reason to believe, we could produce for ourselves. This gives an opportunity to agriculture at the present time, when the outlook seems so very black. It is, indeed, recognised generally that what is required in connection with agriculture at the present time is some practical remedy, as distinguished from general statements deploring the present unprofitable conditions which exist in farming. With figures such as have been cited, it would certainly appear as if pig breeding and bacon curing would offer a promising field for the present-day farmer's enterprise, as there is no doubt at all that the British nation will continue to

consume bacon and pig products whether they are produced at home or imported from overseas. It is notable also that the home-produced article has always commanded a higher price than any imported article, English, Scottish, or Irish bacon figuring in our provision shops invariably at prices higher than those of any others.

It is usual in speaking of imported bacon to think of such countries as Denmark, Sweden, Holland, the United States of America, and Canada, but it must not be forgotten that we have close at our doors in Northern Ireland a rapidly developing industry in connection with pig breeding. In Northern Ireland bacon and ham curing has been practised on a large scale for over 100 years, and, now that there are settled conditions in the country, rapid progress is being made, and greater quantities of pig products are being produced from year to year. It is a significant fact that during 1921 the imports from Northern Ireland for pig products amounted to £2,500,000, and this may be taken as being only a small proportion of the total produce, as in Northern Ireland pig products are consumed to a very great extent. It is customary to slaughter the pigs on the farms, and the carcases are then offered for sale in central markets throughout the province. These carcases are purchased by the various curers, and in this way the offals are retained by the farmers. It is a bad system, as the centralising of the business enables large quantities of offals to be handled in an economical manner, and the use of modern mechanical refrigeration also prevents that certain loss which marketing in this way involves. Notwithstanding these drawbacks, it is of interest to note that the pig industry is one of the first to which attention has been seriously directed in Northern Ireland since the settlement between the North and the South; and there is every likelihood that the exports to Great Britain from there will continue to increase by leaps and bounds.

LOUDON MACQUEEN DOUGLAS.

GENERAL NOTES.

ROADS IN CHINA.—During the year the Good Roads Association of China was organised with headquarters in Shanghai, for the purpose of educating the people throughout the country as to the advantages of good roads and devising ways and means for the financing and construction of highways. The movement has made marked progress, according to the *Shanghai Trade Report*, 1921, considerable interest being displayed by many of the military governors, who apparently see the opportunity of utilising their soldiers in the building of motor roads, which will be of value both from a military and commercial standpoint. In many centres private enterprise has been responsible for much good work. Although the progress in Kiangsu was not so marked as in some other parts of the country, nevertheless the province has to-day 25 roads either constructed or under construction. Automobile roads have been completed from Shanghai to Lunghwa, Chelin and Taitsang and motor-buses are in operation. A survey of the Shanghai-Hangchow road is being made, and a section has already been constructed at the Hangchow end by General Lu Yung-hsiang's soldiers. The city of Nantungchow is planning a network of roads to connect it with all its neighbouring cities.

IVORY TRADE OF ADEN. — The principal existing sources of supply for elephant ivory include the wild districts of western and southern Abyssinia. Before the war an average of 5,000 pounds of this ivory was shipped annually direct to the United States through the port of Aden. Since 1916, however, owing to export prohibition and lower prices, these shipments have ceased. According to a report by the United States Consul at Aden, the great bulk of Abyssinian ivory reaches the world through Aden, though there are some direct shipments from Djibouti. A certain amount also goes through Eritrea, and part of this proceeds to Aden for reshipment. Recently some ivory has gone out through Italian East Africa, and still other quantities go down the Nile through the Sudan. The ivory from southern Abyssinia reaches the world market largely through British East Africa. Great Britain was the principal purchaser of ivory before the war, but has since been displaced by India. It is said, however, that the better quality is sent from India to England. Imports of ivory into Aden amounted to 31,892 pounds in 1913-14, 9,016 pounds in 1918-19, 36,172 pounds in 1919-20, and 49,694 pounds in 1920-21. During the same years the ivory exports from Aden totalled 34,557 pounds, 15,582 pounds, 58,798 pounds, and 36,336 pounds, respectively.

INSECT DAMAGES TO THE FORESTS OF SAGHALIEN.—During 1921, the forests of the southern half of Saghalien (Japanese) have suffered severely from an insect known as Matsukemushi (*lasiccampidæ*). According to information obtained by the United States Consul at Yokohama, from the company owning the greater portion of the forests, there were 85,750 acres of timber destroyed by this insect during 1921, or about 300,000,000 cubic feet of standing timber. It is reported that some of the timber can still be used if cut within a year. On account of the damages by this insect, fires and additional needs of timber for pulp, building purposes, charcoal, etc., the plan to cut the Saghalien forests over a period of 100 years has been changed to 80 years. A natural reafforestation policy

is futile, and to counteract the losses there have been new experimental reservations opened of 7,350 acres, together with a nursery of 392,000 acres, to grow Todo, Ezo and Kara pines. If this policy proves successful, it is hoped to be able to reduce the price of the Saghalien timber, delivered at the coast, to about one-fourth the present price.

MEETINGS OF THE SOCIETY.

Ordinary Meetings.

Wednesday evenings, at 8 p.m. :—

January 24.—Sir William Henry Bragg, K.B.E., M.A., D.Sc., F.R.S., Quain Professor of Physics, University of London, "The New Methods of Crystal Analysis, and their Bearing on Pure and Applied Science." (Trueman Wood Lecture). Alan A. Campbell Swinton, F.R.S., late Chairman of the Council, will preside.

January 31.—Thomas H. Fairbrother M.Sc., F.I.C., and Arnold Renshaw, M.D., D.P.H., "The relation between Chemical Constitution and Antiseptic Action in the Coal Tar Dyes." Sir Humphry D. Rolleston, K.C.B., M.D., D.C.L., President of the Royal College of Physicians, will preside.

February 7.—Charles R. Darling, F.Inst.P., A.R.C.Sc.I., "Electrical Resistance Furnaces and their Uses." Sir Robert A. Hadfield, Bt., D.Sc., F.R.S., will preside.

February 14.—W. J. Rees, Lecturer on Refractories in the University of Sheffield, "Progress in the Manufacture of Refractories."

February 21.—C. Ainsworth Mitchell, M.A., F.I.C., "Handwriting and its value as Evidence." Sir Richard D. Muir will preside.

February 28.—Professor W. E. S. Turner, D.Sc., Head of Department of Glass Technology, The University, Sheffield, "Heat Resisting Glasses."

March 7.—Edward Percy Stebbing, M.A., F.L.S., Professor of Forestry, University of Edinburgh, "The Forests of Russia."

March 14.—Sir William Warrender Mackenzie, K.B.E., K.C., President of the Industrial Court, "Industrial Arbitration." Lord Askwith, K.C.B., K.C., D.C.L., Chairman of the Council, will preside.

Indian Section.

Friday afternoons at 4.30 o'clock.

February 16.—J. T. Marten, I.C.S., M.A., Imperial Census Commissioner in India, "The Indian Census of 1921." Sir Edward A. Gait, K.C.S.I., C.I.E., Member of the India Council, will preside.

June 15.—Sir John H. Marshall, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture).

Dominions and Colonies Section.

Tuesday afternoon at 4.30 o'clock.

March 6.—Major E. A. Belcher, C.B.E., Assistant General Manager, British Empire Exhibition, "The Dominion and Colonial Sections of the British Empire Exhibition, 1924."

Dominions and Colonies and Indian Sections. (Joint Meetings).

Tuesday or Friday afternoons at 4.30 o'clock.

March 16.—Lieut.-Col. Sir Leonard Rogers, C.I.E., F.R.S., F.R.C.P., F.R.C.S., Physician and Lecturer, London School of Tropical Medicine, "Recent Advances towards the Solution of the Leprosy Problem."

April 20.—Sir Richard A. S. Redmayne, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S., "The Base Metal Resources of the British Empire."

May 1.—L. Guy Radcliffe, M.Sc. (Tech.), F.I.C., "The Essential Oils of the British Empire."

Dates to be hereafter announced:

William Arthur Bone, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Recent Developments in Surface Combustion."

Maurice Drake, "The Development of Mediæval Technique in Stained Glass Windows."

Edward Parnell, "The Resources and Trade of Sarawak."

Cantor Lectures.

Monday evenings, at 8 o'clock.

Henry P. Stevens, M.A., Ph.D., F.I.C., "The Vulcanisation of Rubber." Three Lectures. February 5, 12, 19.

J. E. Sears, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards, "Length Measurement." Three Lectures. March 5, 12, 19.

E. Kilburn Scott, Assoc.M.Inst.C.E., M.I.E.E. "The Fixation of Nitrogen." Three Lectures. April 9, 16, 23.

Howard Lectures.

Monday evenings at 8 o'clock.

Stanley S. Cook, "Recent Improvement in Steam Turbines." Three Lectures. April 30, May 7, 14.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

Monday, January 22 .. Geographical Society, Lowther Lodge, Kensington Gore, S.W., 5 p.m. Mr. P. Lake, "Wegener's Hypothesis of Continental Drift."

British Architects, Royal Institute of, 9, Conduit Street, W., 8 p.m. Messrs. R. Knott and W. E. Riley, "The London County Hall."

Mechanical Engineers, Institution of, Storey's Gate, Westminster, S.W., 7 p.m. (Graduates' Section). Discussion on "The Value of College Training to Engineers."

University of London, University College, Gower Street, W.C., 6 p.m. Professor L. W. Lyde, "The Geographical Setting of Some Economic Problems." (Lecture I.)

Rubber Industry, Institution of, Midland Hotel, Manchester. Mr. H. E. Potts, "Patents: As they Affect the Rubber Industry."

Tuesday, January 23 .. Civil Engineers, Institution of, Great George Street, S.W., 6 p.m.

Anthropological Institute, 50, Great Russell Street, W.C., 8.15 p.m., Anniversary Meeting.

Royal Institution, Albemarle Street, W., 3 p.m. Professor F. G. Donnan, "Semi-Permeable Membranes and Colloid Chemistry." (Lecture II.)

University of London, University College, Gower Street, W.C., 5.30 p.m. Professor W. M. Flinders Petrie, "Royal Burials in Ancient Egypt."

Photographic Society, 35, Russell Square, W.C., 7 p.m. Address by Mr. F. C. Tilney (Pictorial Group).

Sociological Society, 65, Belgrave Road, S.W., 4.45 p.m. Dr. C. W. Salesby, "Sunlight and City Life."

Colonial Institute, Hotel Victoria, Northumberland Avenue, W.C., 4 p.m. Mr. A. Miller, "The South East Coast of Africa and its Development."

Oriental Studies, School of, London Institution, Finsbury Circus, E.C., 5 p.m. Professor Sir T. W. Arnold, "Survivals of Sassanian and Manichaen Art in Persian Painting."

Wednesday, January 24 .. Geological Society, Burlington House, Piccadilly, W., 5.30 p.m. (1) Rev. Charles Overy, "Glacial Succession in the Thames Catchment-Basin." (2) Dr. S. H. Haughton, "On Reptilian Remains from the Karroo Beds of East Africa."

Industrial League and Council, Caxton Hall, Westminster, S.W., 7.30 p.m. Mr. H. H. Elvin, "Education as a Function of Management."

Bankers, Institute of, 34, Clements Lane, E.C., 5.45 p.m. Mr. E. R. Long, "That the Permanent Retention of Women Clerks in the Banks on the lines of the Civil Service is desirable, both from the Point of View of the male staffs, and that of the Economical Conduct of Banking Business."

Public Health, Royal Institute of, 37, Russell Square, W.C., 4 p.m. Dr. W. T. G. Pugh, "Surgical Tuberculosis in Children."

Microscopical Society, 20, Hanover Square, W., 7 p.m. Inaugural Meeting to deal with the Industrial Applications of the Microscope. Demonstrations and Exhibits.

8 p.m. (1) Professor F. J. Cheshire, Opening Address. (2) Dr. F. J. Brislee, "Training in Practical Microscopy and the Necessity of Providing Facilities for more Definite Instruction." (3) Dr. J. S. Owens, "Atmospheric Pollution."

Thursday, January 25 ... Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.

Royal Institution, Albemarle Street, W., 3 p.m. Hon. J. W. Fortescue, "The Campaigns of the British Army, 1815-38."

University of London, at University College, Gower Street, W.C., 5.30 p.m. Professor E. G. Gardner, "Italian Poets in the French Revolution"; at the London Hospital Medical College, Mile End, E., 4.30 p.m. Mr. W. A. M. Smart, "The Mathematical Basis of Physiological Problems" (Lecture II.); at King's College, Strand, W.C., 5.30 p.m. Professor W. Barthold, "The Nomads of Central Asia" (Lecture II.)

Structural Engineers, Institution of, 296, Vauxhall Bridge Road, S.W., 7.30 p.m. Mr. W. J. H. Leverton, "The Relations between the Architect and the Engineer."

Optical Society, Imperial College of Science, South Kensington, S.W., 7.30 p.m. Mr. W. Day, "The Birth of Cinematography and its Antecedents."

Royal Society, Burlington House, Piccadilly, W., 4.30 p.m.

China Society, at the School of Oriental Studies, Finsbury Circus, E.C., 5 p.m. Colonel P. T. Etherton, "The Heart of Asia."

Camera Club, 17, John Street, Adelphi W.C., 8.15 p.m. Mr. H. Wrench, "Our Old Village Churches and their Story."

Dyers and Colourists, Society of, Dyers' Hall, Dowgate Hill, E.C., 7 p.m. Mr. T. F. Bradbury, "The Application of Colour to Leather."

(Bradford Junior Section), Technical College, Bradford, 7 p.m. Mr. E. V. Chambers, "The Treatment of Waste Scouring Waters."

(Leeds Junior Branch), University, Leeds, 7 p.m. Mr. F. W. Richardson, "Food Colourings."

Mechanical Engineers, Institution of (Midland Branch), University, Edmund Street, Birmingham. Joint meeting with local branches of Institution of Civil and Electrical Engineers.

London County Council, at Geffrye Museum, Kingsland Road, E., 7 p.m. Professor B. Pite, "Woodwork before Elizabeth."

Friday, January 26 .. Royal Institution, Albemarle Street, W., 9 p.m. Sir Almroth Wright, "The Machinery of Anti-Bacterial Defence."

Photographic Society, 35, Russell Square, W.C., 8 p.m. Mr. H. Cox, "Mesopotamian Exposures."

Physical Society, Imperial College of Science, South Kensington, S.W., 5 p.m.

Anglo-Batavian Society, Birkbeck College, Breams Buildings, Chancery Lane, W.C., 6 p.m. Sir Walter Townley, "The Dutch Painter Vermeer."

Saturday, January 27 Royal Institution, Albemarle Street, W. 3 p.m. Sir Walford Davies, "Speech Rhythm in Vocal Music." (Lecture II.)

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FRIDAY, JANUARY 26, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

NOTICES.

NEXT WEEK.

WEDNESDAY, JANUARY 31st, at 8 p.m. (Ordinary Meeting.) THOMAS H. FAIRBROTHER M.Sc., F.I.C., and ARNOLD RENSHAW, M.D., D.P.H., "The relation between Chemical Constitution and Antiseptic Action in the Coal Tar Dyes." SIR HUMPHRY D. ROLLESTON, K.C.B., M.D., D.C.L., President of the Royal College of Physicians, will preside.

SEVENTH ORDINARY MEETING.

WEDNESDAY, JANUARY 17th, 1923; DR. THOMAS MORISON LEGGE, C.B.E., D.P.H., H.M. Medical Inspector of Factories, in the Chair.

The following candidates were proposed for election as Fellows of the Society :—

Acton, Murray Adams, London.
Ayer, S. K., B.A., South India.
Beaumont, R. H., Wollaton, nr. Nottingham.
Carpenter, Charles L., Porto Rico, West Indies.
Carrier, Willis H., Newark, New Jersey, U.S.A.
Fremantle, Alan Frederick, London.
Gillespie, John, F.S.A. (Scot.), Pollokshields, Glasgow.
Hardless, Charles, Chunar, India.
Hardless, Charles, jun., B.A., Chunar, India.
Hardless, Harold Richard, Chunar, India.
Harkness, Gustavus, Spring City, Pa., U.S.A.
Herring, John P., Bloomsburg, Pa., U.S.A.
Jillson, Willard Rouse, B.S., M.S., Sc.D., Frankfort, Kentucky, U.S.A.
Kar, Upendranath, M.A., B.E., Calcutta, India.
Kodaisia, A. P., Chhatarpur State, India.
Lim Kim Seng, Singapore, Straits Settlements.
Mallik, N. D., Karachi, India.
Nosworthy, Frederick, London.
Pudumjee, Khan Bahadur B.D., Bombay, India.
Ratcliffe, Ellis, Keighley.
Rice, Prof. Ambrose Clark, B.Sc., B.Ph., Grand Island, Nebraska, U.S.A.
Russell, David, LL.D., Markinch, Fife.
Seddon, S. H., M.I.M.E., Calcutta, India.
Singh, Raja Bahadur Naba Kishore Chandra, Hindol, Orissa, India.
Singh, S. Govinda Prasad, Mirzapur, U.P., India.
Spreat, Captain S. H., London.
Stuart, Nigel, New York City, U.S.A.
Tannan, Mohan Lal, B.Com., Bombay, India.
Towne, George Lewis, A.B., Lincoln, Nebraska, U.S.A.
Volck, William Hunter, Watsonville, California, U.S.A.
Wood, Prof. Edwin Ellsworth, M.A., LL.D., Williamsburg, Kentucky, U.S.A.
Zwally, E. L., Pittsburgh, Pa., U.S.A.

The following candidate was duly elected a Fellow of the Society :—

Toplis, Henry, A.M.I.Mech.E., Burnage, near Manchester.

A paper on "Hygienic Methods in Painting—the Damp Rubbing-down Process" was read by Mr. C. A. Klein.

The paper and discussion will be published in a subsequent number of the *Journal.*

INDIAN SECTION.

FRIDAY, JANUARY 19th, 1923; THE RIGHT HON. VISCOUNT PEEL, G.B.E., Secretary of State for India, in the Chair.

A paper on "A Clash of Ideals as a Source of Indian Unrest" was read by THE EARL OF RONALDSHAY, P.C., G.C.S.I., G.C.I.E., late Governor of Bengal.

The paper and discussion will be published in a subsequent number of the *Journal.*

BINDING COVERS FOR JOURNALS.

For the convenience of Fellows wishing to bind their annual volumes of the *Journal,* cloth covers can be supplied, post free, for 2*s.* each, on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES

BROWN COALS AND LIGNITES.

By WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology.

LECTURE I.—*Delivered November 27th,* 1922.

In introducing to you the subject of "Brown Coals and Lignites" I am, in a sense, placed at a disadvantage, in that as recently as February last I read a paper upon it before this Society. The Course of Lectures that I am now beginning is primarily intended to fill in and amplify the outline which I then presented. I shall necessarily have to repeat much of what was said then, but the subject is of sufficient importance to justify such repetition; and, therefore, I hope that those who may have heard or read my previous paper will accept this explanation and extend to me their kind indulgence on the present occasion. I may also, perhaps, be allowed to mention that, realising their future importance to the Empire as a whole, special attention has been given for some years past to the experimental investigation of brown coal and lignites from all parts of the Dominions in the Fuel Laboratories (Department of Chemical Technology) of the Imperial College of Science and Technology, London, and that these Lectures are, in part, based upon some of the results thereof.

THE ORIGIN AND CLASSIFICATION OF BROWN COALS AND LIGNITES.

Coals may be conveniently divided into five principle genera, namely (*a*) Brown coals and lignites; (*b*) Sub-bituminous; (*c*) Bituminous; (*d*) Semi-bituminous, and (*e*) Anthracitic, of which the two first are, generally speaking, of more recent origin than the other three. They may all be considered as representing some stage or product of the primary decomposition and subsequent transformation of the vegetable debris of primeval forests and swamps. The process has gone on since carboniferous times in most of the great geological epochs; and, so far as its earlier stages are concerned, it is being repeated in our peat bogs and deltas, where water-logged vegetable debris is decomposing under bacterial influence.

Whilst it is not my object to discuss at any length the origin and mode of formation of brown coals and lignites, about which there is some difference of opinion, yet a passing reference to the matter will perhaps assist us in judging of their character and value in relation to other coals. From a chemical standpoint, I can see as yet no adequate reason for rejecting the orthodox view that they are intermediate forms between peat and bituminous coals, although our present ignorance of the subject imposes upon us the duty of expressing it guardedly as a provisional hypothesis. In this connection I am well aware of some recent criticism of this view by two German authorities (E. Donath and A. Lissner), who have concluded that coal is not to be regarded as necessarily derived from peat as found in recent deposits, or from common brown coals such as exist now, and that brown coals have originated from vegetable debris different in character from that which in carboniferous times gave rise to our present bituminous coals. This is a view which demands and will no doubt receive, careful attention on the part of scientific investigators; but even if it ultimately proves to be correct, it would not, in my opinion, necessarily dispose altogether of the orthodox view, but rather only modify it.

The original vegetable debris from which all coals have been formed, must have consisted for the most part of ligno celluloses *plus* a certain proportion (probably not exceeding 10 to 20 per cent.) of vegetable proteids. It would also probably contain, besides the foregoing main components, a certain small amount of resins, and it would be mingled with more or less mineral matter.

We must picture then vast masses of such water-logged material decaying, either upon the actual site of its original growth (as in a peat bog), or after being macerated into a pulp and transported and deposited by water in some other low-lying swampy area. In this stage it would be subjected to the decomposing actions of both aërobic fungi and anaërobic organisms, whose relative influences would depend upon the varying water level in the bog; with the result that the larger proportion of it would be resolved into gases (methane and carbon dioxide) and water vapour, leaving an amorphous or gelatinous residue comprising the more stable and resistant parts of the

original debris *plus* a large amount of water. Thus it has recently been concluded by Fischer and Schrader that, as a result of such bacterial action, the cellulose was entirely decomposed and removed from the plant debris, and that the coal was formed by the conversion of lignin into humic substances. I am inclined to think there may possibly be something in such a view, because, in the course of some recent researches which have been made in my laboratories upon brown coals, fairly considerable amounts of aliphatic or alicyclic compounds have been isolated of a character such as might be expected to have been derived from lignin constituents.

It is probable that, during the peat-bog fermentation stage, some portion of the fermented residue would be reduced to a condition of colloidal solution which, on subsequent slow evaporation and drying, would give rise to a *gel*, whilst the more complex resistant part would be in a condition of ordinary admixture with, or suspension in, water. In this connection I may say that, during the course of investigations made in my laboratories upon humic bodies extracted by special solvent treatment from bituminous coals, it was found possible to get them into a state of colloidal solution in alcoholic potash, which on saturation with either hydrogen chloride or carbon dioxide yielded a flocculent precipitate of acidic substances. On being subsequently dried they shrank enormously, finally leaving a lustrous black and structureless mass with conchoidal fracture closely resembling the bright bands in bituminous coals, for which the name "vitrain" has been proposed. Such experiments led us to put forward the suggestion that the bright bands of vitrain found in modern bituminous coals may have been formed originally from a colloidal gel, whereas the dull layers were formed from more complex molecular aggregates which have not passed through such a state of colloidal solution. However that may be, it seems highly probable that, during the fermentation and maceration of the original debris which characterised the peat-bog stage, a considerable amount of segregation, through the agency of water, of the various molecular aggregates according to their complexities would take place in the manner suggested. I would also remind you that the raw peat in a well-drained bog contains as much as 90 parts of water to 10 parts of the peat substance.

In course of time, this rotted debris would either be overlaid *in situ* (during a subsequent period of subsidence) with layers of water-deposited sands or clays, or be transported by water and deposited in some other lower-lying locality, where it would be similarly overlaid with mineral matter. In either case, under the influence of a slowly increasing pressure, its water-content would gradually diminish, with the result that its combustible matter would be gradually consolidated. Under such conditions, it would be slowly transformed into something resembling the most recent types of amorphous and non-laminated "brown coals," which are of tertiary origin, and usually lie not far below the surface. They still contain a large proportion of water, in some cases as much as 50 per cent.; they are termed Earthy Brown Coals, and to the naked eye are usually devoid of any organic structure. As typical examples may be mentioned (*a*), the Morwell brown coal deposits in Australia, about which more later on, and (*b*), the German brown coals, which occur in beds of either miocene or oligocene age in Saxony, Brandenberg, and in the Rhine Provinces.

Besides such "amorphous" brown coals, and probably of similar recent formation, there are occasionally found varieties which have a decidedly woody appearance and fibrous structure. As a good example of this class may be instanced the Valdarno deposits which occur in lower Pliocene measures in a mountain chain separating the valley of the Arno from that of Chianti in Northern Italy. Their "woody" character is so marked that they can often be sawn into pieces without crumbling. They have a chocolate brown colour, and in the raw state contain between 40 and 50 per cent. of water. Their outward appearance suggests that they have been formed from wood which, instead of having passed through the usual "peat bog stage," has undergone a less drastic decay, not involving the disappearance of their woody character. Such fibrous brown coals are a distinct class by themselves, and may perhaps have been formed under somewhat different conditions from other varieties.

In cases where the incipient earthy "brown coal" deposits became in course of time buried more and more deeply under accumulations of newer mineral strata, a "blanketing" effect would be

produced, with consequent gradual increase in both temperature and pressure. A similar effect would also be produced by earth-movements. This would cause primarily a progressive desiccation of the coal; and contemporaneously with, or more probably immediately after it, there would begin certain chemical changes, the nature of which will be indicated hereafter, affecting principally the cellulosic constituents, and resulting in a diminution of the oxygen and an increase in the carbon content of the "coal substance" itself. The deposit would thus become gradually more consolidated; in process of time it might acquire a laminated structure; and with increasing carbon content its colour would darken. Slowly it would be transformed into the type of laminated brown or black lignite which is so abundantly found in the Middle Western States of North America (North and South Dakota, Wyoming) and in the province of Saskatchewan, in Canada.

In the course of further "maturing" the chemical change already indicated would proceed towards its completion, whilst the lignite would acquire a shiny black colour and a conchoidal fracture; eventually it would pass into a class which is sometimes termed "Sub-Bituminous" to indicate its intermediate character between the true lignites and the older bituminous coals. Such types are found both in the United States and in the province of Alberta, in Canada, and they are chiefly cretaceous in origin. We thus arrive at the following provisional representation of the wood-coal series:—

THE WOOD TO COAL SERIES.*

0.. WOODY TISSUE (Lignocelluloses) — ↓ (to 1, and directly to Woody Brown Coals)

↓

1.. PEAT (Quaternary) — Water = 90; Combustible = 10

↓

2.. EARTHY BROWN COALS (Tertiary) — Water = 40 to 50; Coal = 50 to 60 — WOODY BROWN COALS. (Tertiary)

↓

3.. LAMINATED LIGNITES (Chiefly Tertiary) — Water = 20 to 40; Coal = 60 to 80

↓

4.. SUB-BITUMINOUS COALS (Chiefly Cretaceous) — Water = 10 to 20; Coal = 80 to 90

↓

5.. BITUMINOUS COALS (Mesozoic Carboniferous) — Water < 10; Coal > 90

↓

6.. SEMI-BITUMINOUS COALS (Carboniferous)

? ↓ ?

7.. ANTHRACITIC COALS (Carboniferous)

In this connection, the following table, taken from Dr. Walcot Gilson's recent book on "British Coalfield," will doubtless be of interest to those wishing to follow further the political aspects of the subject:—

TABLE OF COAL BEARING FORMATIONS.

Era (Group)	Period (System).	Localities, Class of Fuel.
Cainozoic or Tertiary.	Pleistocene.	Peat—Northern Hemisphere.
	Pliocene.	Peat.
	Miocene.	Lignites and lignitic coals of Central Europe.
	Oligocene.	Hungary, Austrian Alps, Moravia, Russia.
Mesozoic or Secondary.	Cretaceous.	N. Germany, Hungary, Rocky Mountains, Alaska, British Columbia, Manitoba, Japan, Borneo.
	Jurassic.	Yorkshire, Brora, Caucasus, Siberia, Japan, Alaska, Spitzbergen.
	Triassic.	S. Germany (Fettenkohle), United States, Tonkin, Yunnan, Japan.

* The author wishes it to be understood that this classification is meant to be provisional only and subject to modification as further knowledge of the subject is gained.

Era (Group)	Period (System).	Localities, Class of Fuel.
Palaeozoic or Primary.	Permian, Permo-Carboniferous.	Central France, South Africa, India, Australia, South America, Antarctic.
	Carboniferous.	True coals and anthracites in N. Europe, N. America, China.
	Devonian.	Russia.
	Silurian.	No fuels.
	Ordovician.	,,
	Cambrian.	,,
Eozoic.	Archæan.	,,

So far as modern research has been able to elucidate the nature of the later stages of the peat-to-coal transformation process, it would appear to have involved essentially the passage through what may be termed pressure distillation process, including (1) de-watering, followed by (2) internal condensations of cellulosic aggregates characterised by simultaneous elimination of steam and carbon dioxide with a consequent gradual increase in the carbon content of the coal, and (3) some amalgamation of this changed cellulosic or humic matter with molecular aggregates resulting from the similar transformation of proteid matter. The whole process of coal formation, so far as it is known to-day, may perhaps best be epitomised in some such provisional diagram as the following :—

OUTLINE OF COAL FORMATION.

(0)

Original Material.

Lignocelluloses.
Vegetable Proteins.
Resins.

(1)

(*a*) FERMENTATION in Peat Bog with Evolution of Gases.

(*b*) MACERATION by water and possibly also SEGREGATION INTO :—
(*a*) Colloidal Solution (gels).
(*b*) Insoluble Matter.

(*c*) TRANSPORTATION by water and RE-DEPOSITION elsewhere.

(2)

(*a*) BLANKETING under newer Strata and CONSOLIDATING and DE-WATERING of Mass by Pressure.

(*b*) EARTH MOVEMENTS producing LAMINATED STRUCTURE.

(3)

BITUMENISATION UNDER PRESSURE AND SLOWLY INCREASING TEMPERATURE.
(*a*) Progressive Dewatering.
(*b*) Loss of CO_2 and H_2O (Cellulosic Condensation).
(*c*) Amalgamation of Cellulosic (Humic) and Protein Matter.
[Pressure—Distillation.]

It would thus appear that brown coals and lignites may be regarded as intermediate products between peat and bituminous coals ; and it is from this point of view that I propose to deal with them in these lectures.

Some Characteristic Properties of Brown Coals and Lignites.

Brown coals and lignites are characterised by the following properties, which, taken together, differentiate them completely from the geologically older bituminous coals, namely, in that :—(i) in the raw state they contain a large amount of water (*e.g.*, generally more than 20 and sometimes even as much as 50 per cent.) ; (ii) on losing this by "air-drying" they usually disintegrate, either crumbling to powder or developing well-marked laminar cracks ; (iii) they are naturally devoid of coking properties ; (iv) in the "dry-ashless" state they usually contain less than 75 per cent. of carbon and more than 20 per cent. of oxygen ; and (v) on carbonisation at 900° they yield upwards of 45 per cent. of "volatiles." Their physical texture varies considerably, but is easily distinguishable from that of bituminous coals. Thus, the most recent brown coals have either an amorphous earthy character or a very woody and fibrous structure ; while the older varieties have either a laminated structure or a well-marked conchoidal fracture. In Table I. is shewn the ultimate compositions of representative examples of the various stages in the peat-coal series.

Geographical Distribution.

Before, however, considering their economic utilisation, it will be convenient now to refer to the geographical distribution of brown coals and lignites, and to their importance to some parts of the Empire.

Although it would be untrue to say that the geological age of a coal necessarily determines its type and properties, yet it is usually found that, at any rate up to the "bituminous" stage, the older the coal the more mature is it likely to be. Thus most of the brown coals and lignites are geologically of tertiary age, whilst those which I have provisionally designated "sub-bituminous" are usually cretaceous.

The tertiary brown or lignitic coals occur chiefly (i) in what may be termed the Pacific borderlands (*i.e.*, in America west of the Rockies, Japan, Australia, New Zealand, and the E. Indies) ; (ii) in regions adjacent to, or in continuation with, the Gulf of Mexico (*i.e.*, Texas, Mississippi, Arkansas, Alabama) ; and (iii) in regions north of the Mediterranean, including the Central European Plain. There is also (iv) a large area in the United States and Canada (comprising N. and S. Dakota, Montana, Wyoming, Saskatchewan, and Alberta) in which coal-forming conditions prevailed

Table I.

Analyses of Typical Peats, Brown Coals, Lignites, Sub-Bituminous and Bituminous Coals.

	Irish Peat	Brown Coals. Italian Valdarno	Brown Coals. Australian Morwell	Brown Lignite Saskatchewan	Black Lignite Malayan	Sub-Bituminous Nigerian	Bituminous Barnsley Hard Steam
% Water in the Raw Fuel	90	40 to 50	50	30 to 40	20	10	2.5
% Ash in the Dry Fuel	4.5	5 to 10	4.0	6 to 12	6 to 10	7.5	2.75
Referred to the Dry Ashless Coal Substance.	%	%	%	%	%	%	%
Carbon	60.2	60.30	65.10	69.25	73.0	75.0	84.70
Hydrogen ..	5.5	5.40	5.00	4.75	5.5	6.0	5.10
N and S ..	2.0	1.95	0.45	1.70	1.5	2.4	2.25
Oxygen	32.3	32.35	29.45	24.30	20.0	16.6	7.95
% Volatiles at 900° C. ..	65	57.8	57.6	48.0	46.5	45	33.0
(Gross Calorific) value K.C.Us. per Kg... ..	5600	5800	5830	6330	6900	7625	8280

during the cretaceous period, and were continued in great luxuriance into the subsequent tertiary period. In this area there are now immense reserves both of "sub-bituminous" coals and lignites in the upper cretaceous and in the later tertiary formations. The "sub-bituminous" coals in this area are usually in the upper cretaceous formation.

THE BROWN COAL INDUSTRIES OF CENTRAL EUROPE.

In pre-war days, the only countries which had systematically worked their brown or lignitic coal resources on any important scale were Germany and Austria-Hungary, in both of which a considerable brown-coal technology had been developed. In order to show the important dimensions to which the brown coal industry of Central Europe had attained before the War, it needs only to be stated that the German output (gross) of brown coals had increased from about 31.6 million tons per annum in 1898, to the astonishingly high figure of 87.1 million tons in 1913; also, that for the year 1913 the Austrian production amounted to 27.4 million tons, and that of Hungary to about 8 million tons. Indeed, during the decade immediately preceding the War (*i.e.*, 1904-13 inclusive), the brown coal output in those regions had expanded in an even greater ratio than that of black coal, a remarkable testimony to the enterprise of our late enemies in matters pertaining to the economic development of their mineral resources.

The principal brown coal mining areas in Germany are :—(1) in Saxony and Brandenburg, where the beds are of Miocene age ; (2) in the Province of Hesse, and (3) in the Rhine Province (Cologne, Bruhl, and Bonn districts) where the beds are chiefly of Oligocene age.

In the Cologne District, which may be taken as a typical example, the main deposit occurs in a large tertiary (Oligocene) bed, comprising white sands, plastic clays, and brown coals, capped by diluvial deposits. It is bounded on the S.W. by the Eifel chalk and on the N.E. by what are described as Devonian formations (shales). These tertiary beds attain a maximum thickness of 300 metres (say, nearly 1,000 ft.). There are two layers of brown coal, the lower one extending over the whole area, but the upper one (which is chiefly worked) covers only a small part. The thickness of the upper coal, which is so near the surface that it can be won at a very low cost, varies between 20 metres in the South and as much as 100 metres in the North (average thickness about 27m.).

The raw coal contains nearly 50 per cent. of water. After being quarried it is subjected to a drying process in a revolving steel cylinder, about 22ft. long and 7ft. 3in. in diameter, inclined at an angle of 6° to the horizon, which is internally heated by exhaust steam passed through a series of tubes. Its moisture content having thus been reduced to about 15 per cent., the coal passes on to the briquetting factory, where it is pressed into briquettes of various sizes for domestic and industrial consumption. The calorific value of such briquettes is said to be about 4,800 K.C.Us. per Kg. (8,640 B.Th.Us. per lb.) ; and although this may seem small compared with that of a good black coal, yet, owing to their low cost of production, which in pre-war days probably did not exceed 10 marks per ton, there is no difficulty in disposing of them profitably for domestic and industrial purposes. German engineers had successfully designed boilers fitted with special types of grates for burning such brown coal briquettes, with "efficiencies" which (it was claimed) sometimes reached as high as 65 per cent. They had also developed a considerable distillation industry whereby, from the resulting crude tars, they obtained valuable burning oils and paraffin, besides a solid fuel residue.

The Austrian brown coal beds principally occur (i) in N.W. Bohemia, near the Erzegebirge borderland between Bohemia and Saxony, where the tertiary formation runs in a direction S.W. by N.E. from the entrance of the Eger to the Elbe, a distance of 160 kilometres, and attaining in places a width of 25 to 30 kilometres, and (ii) in a broad belt of country extending on either side of a line drawn between Vienna and Trieste, and passing through the provinces of Styria, Carinthia and Carniola.

The Bohemian lignites, which chiefly lie within 500ft. of the surface, were in pre-war days worked at a low cost by shallow shafts. In the raw state they were said to contain about 25 to 30 per cent. of water, and to be of a superior quality as such fuels go. At any rate, they were capable of supporting considerable chemical, textile and engineering industries in N.W. Bohemia. About half of the Austrian output was

exported chiefly to Germany, Switzerland, and Hungary.

Time does not permit of my discussing the production of brown coal in Hungary and North Italy; but sufficient has been said to indicate how successfully the Central European peoples had developed their brown coal industries.

THE LIGNITE QUESTION IN THE UNITED STATES.

Although it is estimated that about one-third of her immense potential coal resources are lignites, it was not until the United States entered the war that she began to pay serious attention to the problem of effectively utilising them. They chiefly occur in Texas and Alabama, where the beds are of tertiary origin, and in N. and S. Dakota, Montana and Wyoming, where they are chiefly cretaceous.

In the year 1918 the U.S. Bureau of Mines issued a bulletin (Technical Paper 178) setting forth the importance of scientifically developing the principal lignite fields, and pointing out that into the N. Dakota section alone there were being imported annually from the eastern coalfields no less than two million tons of bituminous coals and one million tons of anthracites, every pound of which ought some day to be replaced by the local lignites. It was estimated that to do this would require the carbonising of about six million tons of lignites annually, which would yield three million tons of a carbonised solid fuel, 60 million gallons of tar distillates, 45,000 tons of ammonium sulphate, besides 18,000 million cub. ft. of surplus gas.

It was also suggested that in Texas, where are large iron ore deposits with limestone near at hand, which up to then could not be smelted because of the high cost of delivering Alabama coke at the furnaces, the production of a carbonised lignite briquette at a cost not exceeding half that of Alabama coke would entirely alter the situation.

Among the specific proposals already put forward by the U.S. Bureau of Mines for the better utilisation of these lignite resources may be mentioned (i) the drying of the raw coals before use, (ii) the employment of the dried fuel in pulverised form for use in cement kilns, steam raising, and furnace operations generally, (iii) the manufacture of dried lignite briquettes for burning under boilers, and (iv.) the manufacture of carbonised lignite briquettes for use in suction-gas producers and as a domestic fuel.

IMPORTANCE OF LIGNITES TO THE BRITISH EMPIRE.

Turning now to the great Federation of Commonwealths known as the British Empire, it may at once be said that, whilst Great Britain itself is almost destitute of lignites (the well-known Bovey Tracey deposit in Devonshire being the only important one), the solution of the various technical difficulties associated with their efficient use is of especial importance to Canada and Australia, as well as to other parts of the Dominions.

CANADA.—Of the estimated Canadian coal reserves, which amount altogether to no less than 1,234,269 million tons, no less than 1,072,627 million tons are of a "sub-bituminous" lignitic class, and occur in the upper cretaceous formation of the province of Alberta.

In the neighbouring province of Saskatchewan, there are two coal-bearing formations, the higher one being of tertiary age, which is comparable with the Fort Union group of N. Dakota, whilst the lower one is cretaceous. The tertiary beds are now being mined, especially in the Souris Valley, and in many places the individual seams run from 8 feet to 16 feet in thickness, and are mostly within 250 feet of the surface. The Saskatchewan reserves alone are estimated to amount to 59,812 million tons. An investigation recently made under my direction in the Imperial College laboratories upon four representative samples from the Souris Valley showed them to be of a laminated lignite class, containing in the raw state between 30 and 40 per cent. of water, which, however, can be reduced to about 18 per cent. by "air-drying." The completely dried coals contained:—

	Per cent.	
Carbon ..	61.6 to 64.5	Gross calorific values 5650 to 5980 K.C. U's per kilogram.
Hydrogen ..	4.2 to 4.7	
Sulphur ..	0.6 to 0.9	
Nitrogen ..	0.6 to 1.0	
Oxygen ..	20.5 to 24.7	
Ash	6.1 to 11.2	

In a report issued by the Canadian Department of Mines in 1914 it was pointed out that, whereas the lignite deposits of Manitoba Saskatchewan and Alberta were close to important cities and towns, yet they could not at that time be used at all for certain purposes. Thus, their use for firing loco-

motives had been strictly forbidden by the Canadian Railway Commission, owing to their liability of emitting dangerous sparks. For domestic purposes they had been used with more or less success, but even in this connection they had proved but a poor substitute for the anthracitic imported from the United States. Evidently investigation was needed to discover some method of modifying the raw coals by previous treatment before use for such purposes; especially in view of the importance of rendering these Provinces independent of foreign sources of fuel. It was suggested that such investigation should in the first instance be directed towards the substitution of these lignites for imported foreign coal in connection with power production and the manufacture of a fuel gas.

The Dominion Government has set up a Lignite Utilisation Research Board provided with funds to carry out researches and investigations upon such lignites, and it was through this Board's courtesy that I received the samples referred to. There can be no doubt as to the vital importance to the whole of Western Canada of a well-organised scheme of exploiting scientifically these immense tertiary and cretaceous coal resources of Alberta and Saskatchewan. I may, perhaps, be allowed to say that at the Imperial College experiments have been made with these coals which lead us to regard the problem of utilising them successfully for power production, domestic purposes, gas-making and the like as for all practical purposes already sufficiently solved to justify further action being taken.

Australia.

Turning now to the brown coal resources of Australia I particularly wish to call your attention to their far-reaching importance, not only to the future of that great country, but also to us here in England in connection with the ultimate solution of some of our great economic problems, and especially that of unemployment which to-day has assumed such terrible proportions. On the last occasion on which I spoke upon this subject here, we were honoured by the presence of the Agents-General for Victoria and South Australia (the Honourable John McWhae and the Honourable Sir Edward Lucas) who afterwards addressed us in glowing terms about the economic prospects of their country. Australia is a great island continent with immense natural resources as yet imperfectly explored and practically untouched. Its present population numbers only 5½ millions, and its climate is magnificent from the point of view of the white races. At present 97 per cent. of its population is of British origin, and it is the object of the Australian Government to confine its immigration to British stock; but whether that desirable policy can be achieved will depend upon the practical interest which the people of Great Britain take in the matter. For the development of such a new country the question of easily won fuel resources and the production of cheap power generated therefrom is of supreme importance, and I now propose to consider how Australia stands in these respects.

I will first of all ask you to look at the accompanying map of Australia. The total area of the country is 2,948,306 square miles, or more than three-fourths that of the continent of Europe. From the point of view of its more immediate economic development an area of a little more than 500,000 square miles, which has been appropriately described as the "Heart of Australia" (shown as a shaded circle in the south-east corner of the map, whose circumference passes through the cities of Adelaide, Melbourne and Sydney,) is of most importance. This area comprises the greater part of the provinces of New South Wales and Victoria as well as part of that of South Australia, and it is watered by the great Murray-Darling River system. Within it are concentrated 70 per cent,

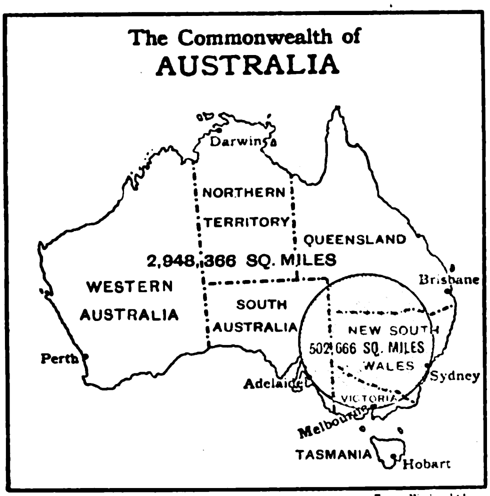

Fig. 1.

of the total population, as well as mos of the known coal resources of Australia and in size it exceeds the areas of France Germany, Denmark, Holland, Belgium and Switzerland all put together.

The coal resources of this area comprise the well-known permo-carboniferous black coal measures and certain triassic lignitic coals in New South Wales, and the more recently-discovered tertiary brown coal deposits located in Victoria and South Australia, and it is to the last-named that I would now direct your special attention.

Extensive deposits of tertiary brown coals occur in the province of Victoria, particularly in the Gippsland and Cape Otway districts. Of these, the celebrated Morwell deposits are of extraordinary thickness without parallel elsewhere in the world, and their economic importance and scientific interest can hardly be overrated. Morwell itself lies in or near the Latrobe Valley, about 90 miles by rail from Melbourne, where extensive faulting took place towards the close of the Miocene period producing enormous depressions, in which large accumulations of vegetable matter were subsequently deposited during the Pliocene times. These originated the present brown coals of that locality. It has been estimated

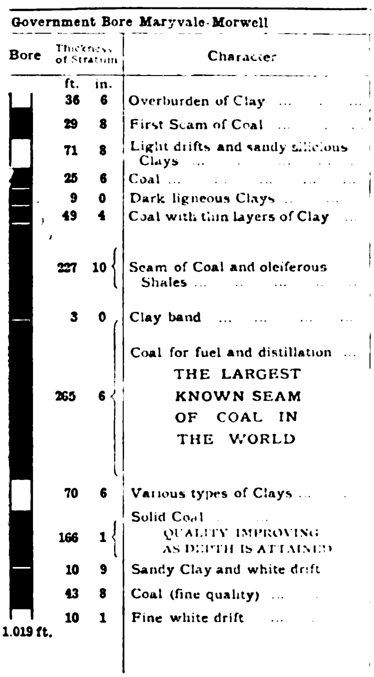

FIG. 2.

that within an area of 50 square miles in the Latrobe Valley and within about one thousand feet of the surface there are 31,144 million tons of the coal A bore-hole put down by the Government near Morwell, a sectional diagram of which is shown herewith, disclosed no fewer than seven beds of brown coal within 1,019 feet of the surface of a total thickness of 781 feet, the individual seams (taken in order from the surface) running 29ft. 8ins., 25ft. 8ins., 23ft., 227 ft. 10ins., 265ft. 6ins., 166ft., and 43ft. 8ins., respectively—a perfectly wonderful store of energy awaiting the service of man. So far as they have been examined, they were reported by the Victorian Advisory Committee on Brown Coal, in 1917, as consisting of "a matrix of earthy brown coal, with sporadic inclusions of lignite . . . the matrix consists of pollen grains, spore cases, and decomposed vegetable matter."

It may be surmised from such a diagram that in going down through such an immense thickness of coal its qualities and degree of maturity will probably improve towards the bottom of the deposit. As yet only the upper and presumably the poorer parts of the deposit have been explored. It seems to me that the Morwell deposit represents a great natural cavity which was filled up in Pliocene times with water-borne vegetable debris which has since been held there, as it were, in a natural filter funnel; and if such a picture is correct, one would expect to find the degree of dehydration and maturing of the coal to increase with the depth below the surface.

The coal lying nearest the surface is an amorphous brown coal of earthy texture, which in the raw state contains about 50 per cent. of water. During the past five years in my laboratories at South Kensington we have carried out a complete chemical investigation of representative consignments of the coal sent us through the courtesy of the Agent-General for Victoria. Our analyses of the dried coal show that it contains on the average :—

	Per cent.
Carbon	62.5
Hydrogen	4.85
Nitrogen	0.45
Sulphur..	0.20
Oxygen	28.00
Ash	4.00

and its gross calorific value is about 5,600 K.C.U's. per kilogram.

In the year 1917, the Government of Victoria appointed an Advisory Committee to investigate and report on the possibilities of utilising the immense resources of brown coal at Morwell for the purpose of generating electric power on a large scale. In due course this Committee reported that, notwithstanding the low grade of the coal, power could be more cheaply generated from it for the City of Melbourne than from black coal imported from New South Wales. It was officially estimated that, about that time, the cost of producing raw Morwell coal at the mines would not exceed two shillings and threepence per ton, and that it could be delivered at the existing railway in Melbourne at seven shillings and eightpence per ton against about twenty shillings per ton for black coal from New South Wales. It was also estimated that the total annual cost, including capital charges, of supplying Melbourne with electricity in bulk from a 50,000 K.W. power station at Morwell, assuming a load factor of 43.2 per cent., would not exceed 0.267 pence per unit.

I am indebted to the courtesy of the Agent-General for Victoria for most of the information as to subsequent developments at Morwell, as also for the photographic illustrations of the Morwell deposits which I am able to show you. Following on the Advisory Committee's Report, the Victorian Parliament passed legislation in December, 1918, appointing a body known as the Electricity Commissioners who were empowered to prepare a scheme for the development of the Morwell deposits for the generation of electricity. The scheme drawn up by the Commissioners was finally authorised by Parliament in December, 1919. It provides for the erection of a generating station on the coalfield, with an initial capacity of 50,000 kilowatts, and to be capable of expansion to at least 100,000 kilowatts, at an estimated cost of £2,500,000. Parliament also adopted a recommendation of the Commissioners that the coalfields should be developed, with a view to supplying cheap brown coal for public consumption, and authority was also given to the Commissioners to erect a large plant for the manufacture of briquettes on a commercial scale. The underlying idea of the whole scheme is to render the State of Victoria independent of the black coal mines of New South Wales, and to provide cheap electric power for the City of Melbourne, the Victorian State Railways, and for the general industrial development of the Gippsland area which is very rich in mineral resources. When the whole scheme has been finally developed, *i.e.*, in about the year 1924, it will probably involve an expenditure of over £6,000,000; and it is hoped thereby:

(i.) To produce the raw coal at Morwell, at a cost of about three shillings per ton;

(ii.) To supply the same in Melbourne at about nine shillings per ton;

(iii.) To supply the City of Melbourne with electric power in bulk at less than one halfpenny per unit.

Indeed, when the Agent-General for Victoria spoke about the Morwell scheme here at my lecture in February last, he said that it was calculated that electrical energy would be furnished to manufacturers at the low rate of £4 8s. per horse-power per annum, and at the mine at £2 17s. 6d. per horse power annum.

With regard to the winning of the coal at Morwell, it is proposed to operate the deposits on the open cut system, removing the overburden, as well as the underlying coal, by means of large steam shovels. The area which it is proposed to work for the present is one square mile, and it is calculated that this is capable of furnishing sufficient brown coal to meet prospective requirements for at least a century.

The character of the operations contemplated may best be judged from the following photographs (all shown on the screen) of which No. 1 is reproduced in the text:—

(i.) Coal deposit showing overburden and uppermost layer of coal.

(ii.) Removal of overburden.

(iii.) Concreting of the foundations for the steam turbines.

(iv.) Ruston shovel at work excavating the switch yard.

(v.) Scene on the River Latrobe which will supply the cooling water for the power station, and the domestic water supply for the new township.

(vi.) Construction camp and temporary works offices accommodating 250 work-people.

(vii.) Cottages for workpeople.

With regard to the erection of the first section of the power station of 50,000 kilowatts capacity, which is now proceeding, the following particulars of plant may be of interest. This section of the station will contain four 12,500 kilowatt turbo-alter-

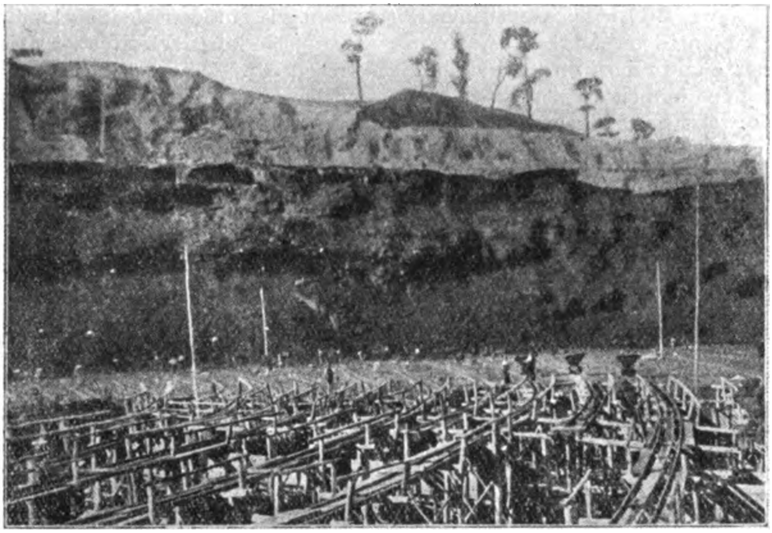

FIG. 3.—Morwell Coal Deposit, showing Overburden and uppermost layers of Coal.

nators running at 3,000 revolutions per minute, and a house set of 800 K.W. capacity used for starting up the larger generators. The whole of the plant is being manufactured by the Metropolitan Vickers, Ltd., of Manchester, and is costing some £300,000 without erection. A contract has also been placed with Messrs. John Thompson, of Wolverhampton, for the supply of twelve boilers, at a cost of about £290,000; whilst the steel buildings comprising the station are being manufactured by the Redpath Brown Co., of Edinburgh. The high tension switch gear was made by the General Electric Co., of America.

Preliminary steps are being taken to the erection of the high tension transmission line from Morwell to Melbourne, a distance of 112 miles. This line is to operate at 132,000 volts, and will consist of aluminium steel reinforced cable strung on galvanised towers spaced about 1,000 feet apart. It will end at the Terminal Station at Newport, near Melbourne, from which the current will be distributed at suitably reduced voltage to the various users in that city.

The Morwell deposit whilst it is the most important, is not the only one in Australia whose economic development is under consideration. I understand, for example, that large deposits of brown coal have been discovered on the banks of the River Murray, in the Province of South Australia, and since I last lectured here, representative samples of it have been submitted to me by the South Australian Government for chemical investigation. It is of a more woody character than the Morwell deposits. Though of about the same calorific value in the raw state, it contains between 50 and 60 per cent. of water, which, on air-drying in Australia, can be reduced to about 16 per cent.

NEW ZEALAND.—According to the report upon the World's Coal Resources, issued by the International Geological Congress in the year 1913, New Zealand's available coal reserves are estimated at 3,386 million metric tons, of which no less than 2,080 million tons (or about 60 per cent.) are brown coals and lignites. The chief coal-bearing rocks are said to be of tertiary age, but it is thought that coal will almost certainly occur in the upper cretaceous formations. The lignite question is, therefore, a very important one for New Zealanders, and already a start has been made with its scientific investigation. I am indebted to an official bulletin issued in 1918 by the New Zealand Board of Science and Art for the detailed results of some gas-producer and low-temperature distillation trials carried out on the native brown coals by some of its National Research Scholars. Up to then the work, although excellently begun, seems to have been rather of a preliminary character; but it will, doubtless, be duly pressed forward to completion.

INDIA.—Through the kindness of Mr. Cyril S. Fox, of the Geological Survey in India, who is now in this country, I am able

to give the following particulars concerning the occurrence of lignites in that country. Mr. Fox has written as follows :—

"Beds and lenticular patches of lignite "occur in association with cretaceous and "tertiary strata in various parts of India. "(i) Lenticular patches have been found "in Ross and Viper Islands at Port Blair "in the Andamans. (ii) In the Dirjum "gorge at the foot of the Abor hills and "between Pasighat and Janak-Mukh in "Assam. (iii) Deposits have been reported "and examined along the foot hills of the "Himalaya in the Darjeeling District and "near Baxa and Jainti in the Jalpaiguri "District of Bengal. (iv) The lignite of "Ratnagiri in the Bombay Presidency has "been known for some time. (v) Occur-"rences have been recorded from Burma, "near Kindat, in Chindwin (Upper); near "Talang in the Kachin hills of Myitkyina; "in the neighbourhood of Kyeintali in the "Arakan Hill Tracts of Sandaway; and "near Hsikip and about Nangon in the "South Shan States. (vi) Deposits occur "in the Raipur District of the Central "Provinces at Bhatagaon, Chugwa and "Jumrao. (vii) The occurrences in Canna-"nore, Bepur and Warkalli of Malabar in "the Madras Presidency are important. "It is estimated that 276 million tons of "lignite are available in the coastal tract "of Travancore. (viii) Two deposits, near "Katmandu and Etaunda, occur in Nepal. "(ix) Extensive beds of lignite were en-"countered in boring operations in the "coastal tracts between Pondicherry and "Cuddalore at Bahour, Aranganur and "Koniakovil. The depths at which these "beds, varying from 25 to 50 feet thick, occur "were 275 feet, 203 feet, and 330 feet re-"spectively. An average sample analysed "by Mallett gave: Carbon, 25.2%, Volatile "matter, 29.1%; Water, 35.3% and Ash, "10.4%. (x) The jet coal of Kalabagh in "the Mianwali District and the exposures "in Nerh Hill, near Murree, in the Rawal-"pindi District are the reported discoveries "of the Punjab. (xi) Lignite occurs in "several places, *i.e.*, near Kalka, Siliani, "Kalawala, Kotdwara, etc., along the "Siwalik foot-hills of the United Provinces.

"The lignite beds of the Malabar Coast, "particularly in the Travancore country, "do not appear to have received the serious "attention they deserve. The matter is "the more urgent when it is appreciated "that 90% of the coal production of India "is obtained from the so-called Bengal "Coalfields of Raniganj, Jherria and "Giridih, and that the railway transporta-"tion facilities from this region are "admittedly inadequate. It is only too "well known that any dislocation of the coal "traffic from this area, either as a result "of labour trouble or other causes, seriously "affects the various industries which depend "on the supply of coal from the above "fields. The recent establishment of great "steel and iron works and the projected "erection of similar larger plants in the "neighbourhood of the Bengal coalfields "must lead to strict economies in the "utilisation of the valuable coking coals "of these fields. It would, therefore, "seem that the time has come for a con-"sideration of the decentralization of the "coal supply of India. By the development "of other fuel resources of the country, "it is possible that cheaper fuel may be "obtainable in certain more distant "industrial areas now dependent on Bengal "coal. It is also likely that a stimulus "will be given to the local commercial "activity of those tracts which have peculiar "industrial potentialities."

Burma and the Malay Peninsula.—Important deposits of well-matured lignites have been found in both these countries; but our knowledge of their resources of such coals is as yet very imperfect.

At Rawang (Malaya) a coal area has been opened out, and is being developed by the Malayan Collieries Company, Ltd. The coal-bearing series in that neighbourhood are said to consist of shales and sandstones resting on a foundation of quartzite and slates, and are thought to be of tertiary age. There are two seams, the upper of which exceeds 24, and may possibly attain to 50 feet in thickness. Extended trials of this coal have been made with the object of testing how best it may be utilised for various purposes, such, for example, as steam raising and power-gas production. Also large-scale low temperature distillation trials have been carried out, with most interesting results, both as regards the character of the various oils and other by-products obtainable, and the manufacture of a briquetted smokeless steam-raising fuel from the carbonised residue.

The raw coal is a well-matured brown-black laminated lignite, in some respects

almost "sub-bituminous" in type, containing about 20 per cent. of water. The completely dried coal contains:—

Carbon=67.9; Hydrogen=4.7;
Nitrogen=1.0; Sulphur=0.4;
Oxygen=19.6; and Ash=6.0 per cent.

Its gross calorific value (dry) is about 6,100 K.C.U's. per kilogram, or, say 11,000 B.Th.U's. per lb.; and when carbonised at 900°C., it yields about 43.75 per cent. of "volatiles."

OBITUARY.

ARTHUR T. WALMISLEY, M.Inst.C.E.—Mr. Arthur T. Walmisley, whose death took place at Folkestone on the 18th inst., at the age of 74, was a very old member of the Royal Society of Arts, having been elected in 1874. In 1910 he read a paper here on "The Port of Dover." He was the eldest son of the late Arthur Walmisley, of the Foreign Office, and was for many years engineer to the Dover Harbour Board, and he had been Mayor of Dover. He was recognised as an authority of the construction of bridges and roads.

FRENCH PRIMARY PERFUME MATERIALS.

Grasse, in the Department of Alpes-Maritimes' is the centre for the manufacture in France of the primary materials used in making perfumery, such as floral concretes (produced by the action of petroleum ether dissolving the wax containing the scent of the flowers), enfleurage (obtained by the absorption of the flower scents in grease), and essential oils (obtained by distillation of the blossoms). The annual output of these commodities is estimated at more than £4,000,000. Furthermore, floral products distilled in other parts of southern France are, to a great extent, handled commercially at Grasse.

Before the war synthetic perfumery was manufactured chiefly in Germany. At the present time several of the larger plants at Grasse are making it but in such small quantities compared with the pure floral products, as not to enter into serious consideration.

According to a report by the United States Vice-Consual at Nice, all the available land around Grasse is reserved for the cultivation of flowers, and the value of the Grasse products is based on the prices of the flowers, which vary considerably from year to year with the harvest. While, as can be seen from the following table, prices during 1922 were well below those of 1921 for several varieties and in some instances were only a fourth or a fifth of the prices in 1920, all are above the pre-war figures:—

Prices of French Flowers.

Varieties.	Before the war.	1920.	1921.	1922.
	Frs.	Frs.	Frs.	Frs.
Jasmine	2.00-3.50	26.00	7.50	6.00
Tuberoses ...	3.15	36.25	12.50	7.00
Parma Violets	4.50	36.00	20.00	...
Victoria violets	...	25.00	10.00	28.00
Violet leaves...	...	.50	.30	.25
Roses	.50- .75	8.40	4.30	1.00
Orange flower	.50- .75	10.20	13.00	4.50-5.75
Cassia	...	20.00	17.50	17.00
Jonquil	2.00	...	12.00	12.40

These quotations are per kilo of 2.2046 pounds.

Jasmine.—The picking of jasmine usually commences about the 20th of July and ends early in September. Jasmine is used principally in the production of enfleurage, and sold as "absolue de jasmin," the average wholesale price last summer being 13,000 francs per kilo, and for jasmine concrete, 2,200 francs.

Tuberoses.—The tuberose blooms from the middle of August until the middle of September. The scent is extracted from the flower in the same way as from jasmine. The average price at the end of August last for "absolue de tuberoses" was 8,500 francs per kilo., and for concrete 1,760 francs.

Parma Violets.—Parma violets were grown in abundance in the environs of Grasse before the war, but the cultivation of this flower has been abandoned, owing, it is stated, to its high price and the consequent prohibitive cost of the violet extract. It is expected, however, that the cultivation of the Parma violet will be resumed in the future. The violets now used are the so-called Victoria violets, which are grown around Hyères (Var). Violet leaves are distilled in large quantities and are used as a basis for violet perfumery. The average wholesale price asked for concrete of Victoria violets is 2,200 francs per kilo, for "absolue of violet leaves" 6,000 francs, and for violet-leaf concrete 1,500 francs.

Roses.—Roses are picked from the beginning of May until the end of June. This year's crop was very abundant, and the flowers were offered in large quantities to the manufacturers at such reasonable prices that the stock on hand of both concrete and essential oil of roses, is very large. The average price of 1,500 to 1,800 francs per kilo for essential oil has fallen to an average of 1,300 francs per kilo.

Orange Flower.—The centre for the cultivation of the orange flower is Valauris, a small town 15 miles from Grasse. Cultivators of this flower have formed a union and own a distilling plant, which enables them to dictate to the perfumers in the matter of price. The flowers

are picked in May and June. The price fixed by the union in the spring of 1922 was five francs per kilo, as the outlook at that time seemed unfavourable. The crop, however, turned out better than was expected (although still below the average), and growers outside the union sold their flowers at 4.50 francs a kilo. The orange blossom is one of the most important flowers for the Grasse industry, as the demand for neroli, or essential oil of the orange flower, concrete, and orange-flower water is large. The average price in August for neroli was 3,300 francs per kilo.

Geranium.—The essential oil of geranium constituted before the outbreak of the war one of the largest exports from Grasse. The principal geranium fields are in Algeria and on the Isle of Bourbon; and while this oil is considered inferior to the Grasse product, it was imported in large quantities to Grasse for re-exportation. Owing to the high cost and difficulties of transportation during the war, the African oil of geranium is now exported direct from the locality of its production. This oil, which in 1914 cost only 38 francs per kilo, was largely used in the soap industry. The price rose exorbitantly during the war, and its use for this purpose was abandoned. The price paid for essential oil of "geranium sur rose," a speciality of the Grasse perfumers, is now as high as 660 francs per kilo.

Cassia.—The cassia harvest takes place in October and November. The concrete of cassia is quoted at about 5,500 francs per kilo, and essential oil as high as 14,000 francs.

Jonquil.—The gathering of jonquils takes place in April and May. This year's crop was a poor one, and consequently the stock on hand at Grasse of jonquil products is small. The average price for "absolue of jonquil" is 5,500 francs per kilo, and for concrete 1,400 francs.

The above-mentioned flowers are the most important for the Grasse perfume industry. Although there are numbers of other flowers, such as the carnation, mignonette, and mimosa, they are of less commercial importance.

The exorbitant prices paid for the primary articles of perfumery in 1920, when the demand was so great that in many cases the manufacturers were not able to fill orders on hand, preceded the slump of 1921, which ended in the practical stagnation of the whole perfume trade. Recently, however, an increasing demand for floral products has been experienced, and orders have been received by most of the Grasse houses for their products at remunerative prices, especially from France, the United States, Germany, and South American countries.

DEVELOPMENT OF QUEENSLAND.

The following particulars regarding the State of Queensland and its agricultural and industrial development, taken from a report by Mr. A. W. Perrin, recently United States Trade Commissioner in Australia, may be of interest as summarising the resources of the State, although the information given is fairly widely known in this country.

Queensland is the second largest of the six Australian States, and constitutes nearly one-fourth of all Australia. It contains 670,500 square miles of land, 98 per cent. of which is owned by the State; 359,000 square miles are within the Tropics and 311,500 in the Temperate Zone.

North Queensland is really tropical, south Queensland is never cold. The State produces wheat, barley, oats, corn, potatoes, apples, and other crops of the Temperate Zone, as well as sugar, pineapples, bananas, papeias, mangoes—all tropical and sub-tropical growths.

Along the east coast runs a low mountain range, from 25 to 100 miles inland; behind the mountains is a belt, perhaps 100 miles wide, of scrub timber, the so-called desert, and beyond the timber belt stretch great treeless prairies, extending north and south from the Gulf of Carpentaria to the New South Wales border line. The coast between the mountains and the sea is well watered and fertile. The rainfall averages 40 to 60 inches annually on the coast, 20 to 30 inches in the desert, and 10 to 20 inches in the western plains, but apprehensions of drought are relieved to some extent by easy access, over most of the prairies, to artesian and sub-artesian water. At Longreach, in the heart of the pastoral district of central Queensland, is an artesian well producing over 3,000,000 gallons of good water a day. In the whole State there are 1,218 artesian flows, 812 of which yield over 100,000 gallons daily, and 1,000 more wells are being drilled.

In minerals the State abounds. Gold, copper, tin, coal, silver, lead, antimony, manganese, iron, molybdenum, arsenic, scheelite, wolfram, bismuth, emeralds, sapphires, and black opals are mined. From one gold mine alone, Mount Morgan, £20,000,000 worth of gold has been produced. The total yield of the State from the discovery of gold in 1860 to the end of 1921 is about £100,000,000. Nearly 1,000,000 tons of coal is produced annually from one field; other large fields are known, but undeveloped. The production of copper in normal years averages about 18,000 tons. The production of tin is considerable, but that of iron and other minerals small, though sufficient to indicate that further exploitation would be profitable. Large deposits of the finest white marble are being worked near Rockhampton.

Queensland is the only Australian State with important softwood forests. Queensland pine, cedar, and maple are exported to Victoria and New South Wales.

Fisheries, especially pearling, are a promising industry.

The population of Queensland is only 758,000, more than one-third of whom live in five coast

and near-coast cities. Outside the ports the density of population is less than one to a square mile; the tropical farthest north is almost absolutely uninhabited.

The agricultural and industrial development of the State is shown by the following figures of annual output of the leading products (average of five years):—

Wool	pounds	113,000,000
Beef	ditto	230,000,000
Mutton and Lamb	ditto	17,500,000
Hides and skins	pieces	421,000
Butter	pounds	32,600,000
Timber:		
Soft	board feet	85,000,000
Hard	ditto	50,000,000
Wheat, Maize and Barley	bushels	4,500,000
Sugar cane	tons	1,800,000
Minerals	value	£3,600,000
Factory output	ditto	£30,000,000

Obviously, the production of sheep and cattle, wool, meat, hides and skins is the principal industry of Queensland, as it is of Australia as a whole. Some 17,000,000 sheep range the broad grass lands of western Queensland. There are also about 5,500,000 cattle in Queensland, which supply the large packing plants in Brisbane, Rockhampton, and Townsville. The sheep and cattle live out of doors all the year round.

Some of the larger sheep stations are principalities. One hundred-and-sixty exceed 100,000 acres each, carrying an average of 42,000 sheep, while a few are measured by square miles, not acres, and carry over 100,000 sheep. Sheep runs of 10,000 acres are common. Practically all the grazing lands, indeed, most of the land of all kinds in Queensland, are owned by the State. Of the total acreage of 429,120,000, only 26,534,978 acres are privately owned, the balance (except 76,709,970 acres unused) being leased, mostly for sheep and cattle runs.

The pastoral country is inadequately served with railways, and it is mainly for railway extension that the State is borrowing money. The mileage of Queensland's existing railway system is about 5,500. The capital cost of the railway system to date is about £42,000,000.

GENERAL NOTES.

Textile Institute, London Section.—A London Section of the Textile Institute has been formed, and premises have been taken at 38, Bloomsbury Square, which will be ready for occupation at an early date. Arrangements are being made for a first course of three Lectures on Textile Raw Materials and Processes (from Fibre to Fabric), and the particulars of this will it is hoped be available for circulation very shortly. The Institute draws its membership from every part of the country, as well as from overseas; and it is hoped that the facilities offered by a London Section may induce country members to join the Institute who have not yet seen their way to do so through any of the existing Sections in Lancashire, Yorkshire, the South of Scotland and Ireland.

Machine for Laying Paper Mulch in Pineapple Cultivation.—According to the official United States "Commerce Reports," the use of paper as a mulch over the soil above the roots of pineapple plants appears to be destined to become a common practice in pineapple culture. In this connection a machine has recently been developed which prepares the bed, lays the paper, and covers its edges in one operation, at very moderate expense as compared with the high cost of the hand method. The three essential parts of the machine (each of which performs a definite function) are a plank drag sled, which pulverizes the soil and forms it into a bed of the desired shape to receive the paper; a flanged roller or spool, which is attached to the rear of the sled and shapes the paper over the bed, turning its edges down into the furrows made by the sled runners, and shovels or discs, which are placed at the back of the flanged ends of the roller and which serve to throw the soil against and over the edges of the paper. The sled may be modified to draw the soil into a bed of any shape desired.

Scottish Bacon.—Extensive operations are being carried on at Thornhill, Dumfriesshire, in connection with the new works being constructed for Messrs. A. Kirkpatrick and Sons, Ltd. The present factory is being doubled in size; and when completed, will be the largest rolled bacon establishment in the world. It is being equipped with the most modern machinery. Lard refining on the most modern plan will form a special feature of the new factory, and there will be large departments for the manufacture of glass goods as well as preserved provisions, food dainties of many kinds, and the final residues will be converted into tankage. The whole of the work is being carried out under the supervision and from the designs of Mr. Loudon MacQueen Douglas, F.R.S.E., Edinburgh, who is responsible for the design of many bacon factories throughout the world.

Scientific Culture of Pearls in Bohemia.—The scientific culture of pearl-bearing oysters has been carried on for a number of years in the Otava River, in southern Bohemia, according to the United States Consul at Prague. The oysters are opened once in eight years. The last examination of the oysters, which took place this year, resulted in the finding of 5 white pearls that may be classed as precious, 25 less valuable ones, and 200 coloured pearls.

MEETINGS OF THE SOCIETY.

ORDINARY MEETINGS.

Wednesday evenings, at 8 p.m. :—

JANUARY 31.—THOMAS H. FAIRBROTHER M.Sc., F.I.C., and ARNOLD RENSHAW, M.D., D.P.H., "The relation between Chemical Constitution and Antiseptic Action in the Coal Tar Dyes." (Mann Lecture.) SIR HUMPHRY D. ROLLESTON, K.C.B., M.D., D.C.L., President of the Royal College of Physicians, will preside.

FEBRUARY 7.—CHARLES R. DARLING, F.Inst.P., A.R.C.Sc.I., "Electrical Resistance Furnaces and their Uses." SIR ROBERT A. HADFIELD, BT., D.Sc., F.R.S., will preside.

FEBRUARY 14.—W. J. REES, Lecturer on Refractories in the University of Sheffield, "The Durability of Refractories." H. J. C. JOHNSTON, President of the Institute of Clay Workers, will preside.

FEBRUARY 21.—C. AINSWORTH MITCHELL, M.A., F.I.C., "Handwriting and its value as Evidence." SIR RICHARD D. MUIR will preside.

FEBRUARY 28.—PROFESSOR W. E. S. TURNER, D.Sc., Head of Department of Glass Technology, The University, Sheffield, "Heat Resisting Glasses." THE HON. SIR CHARLES A. PARSONS, K.C.B., LL.D., D.Sc., F.R.S., will preside.

MARCH 7.—EDWARD PERCY STEBBING, M.A., F.L.S., Professor of Forestry, University of Edinburgh, "The Forests of Russia."

MARCH 14.—SIR WILLIAM WARRENDER MACKENZIE, K.B.E., K.C., President of the Industrial Court, "Industrial Arbitration." LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, will preside.

INDIAN SECTION.

Friday afternoons at 4.30 o'clock.

FEBRUARY 16.—J. T. MARTEN, I.C.S., M.A., Imperial Census Commissioner in India, "The Indian Census of 1921." SIR EDWARD A. GAIT, K.C.S.I., C.I.E., Member of the India Council, will preside.

JUNE 15.—SIR JOHN H. MARSHALL, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture).

DOMINIONS AND COLONIES SECTION.

Tuesday afternoon at 4.30 o'clock.

MARCH 6.—Major E. A. Belcher, C.B.E., Assistant General Manager, British Empire Exhibition, "The Dominion and Colonial Sections of the British Empire Exhibition, 1924." THE RT. HON. L. S. AMERY, M.P., will preside.

DOMINIONS AND COLONIES AND INDIAN SECTIONS. (Joint Meetings).

Tuesday or Friday afternoons at 4.30 o'clock.

MARCH 16.—Lieut.-Col. SIR LEONARD ROGERS, C.I.E., F.R.S., F.R.C.P., F.R.C.S., Physician and Lecturer, London School of Tropical Medicine, "Recent Advances towards the Solution of the Leprosy Problem."

APRIL 20.—SIR RICHARD A. S. REDMAYNE, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S., "The Base Metal Resources of the British Empire."

MAY 1.—L. GUY RADCLIFFE, M.Sc. (Tech.), F.I.C., "The Essential Oils of the British Empire."

Dates to be hereafter announced :

WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Recent Developments in Surface Combustion."

MAURICE DRAKE, "The Development of Mediæval Technique in Stained Glass Windows."

EDWARD PARNELL, "The Resources and Trade of Sarawak."

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

HENRY P. STEVENS, M.A., Ph.D., F.I.C., "The Vulcanisation of Rubber." Three Lectures. February 5, 12, 19.

SYLLABUS.

LECTURE I. February 5th.—An outline of the changes rubber undergoes when vulcanised. Pre-treatment of the raw material. Vulcanisation process. Physical and chemical properties of vulcanised rubber.

LECTURE II. February 12th.—Methods of vulcanisation. Heat treatment. Vulcanising agents. Cold cures. Accelerators. Vulcanisation of rubber sols and gels.

LECTURE III. February 19th. — Measurement of vulcanising effort. Load-stretch curves. Mineral compounding ingredients. Theories of vulcanisation.

J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards, "Length Measurement." Three Lectures. March 5, 12, 19.

E. KILBURN SCOTT, Assoc.M.Inst.C.E., M.I.E.E. "The Fixation of Nitrogen." Three Lectures. April 9, 16, 23.

HOWARD LECTURES.

Monday evenings at 8 o'clock.

STANLEY S. COOK, "Recent Improvement in Steam Turbines." Three Lectures. April 30, May 7, 14.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, JANUARY 29 .. Architectural Association, 34, Bedford Square, W.C., 7.30 p.m. Mr. A. Rutherston, "The Artist Craftsman in the Theatre of To-day."

University of London, University College, Gower Street, W.C., 4 p.m. Professor L. M. Brandin, "Le Chanson de Roland." (In French).

At King's College, Strand, W.C., 5.30 p.m., Professor R. Dyboski, "Poland." (Lecture II.)

Farmers' Club, at the Surveyor's Institute, 12, Great George Street, S.W., 4 p.m. Mr. C. D. Whetham, "The Utilization of Whey."

Geographical Society, 135, New Bond Street, W., 8.30 p.m. Captain J. E. T. Philipps, "Kigezi and the Birunga Range, Uganda."

Victoria Institute, Central Hall, Westminster, S.W., 4.30 p.m. The late Rev. A. C. Robinson, "Three Peculiarities of the Pentateuch which show that the Higher Critical Theories of its late Composition cannot be reasonably held."

Actuaries, Institute of, Staple Inn Hall, Holborn, W.C., 5 p.m. Mr. W. P. Elderton, "Notes on the Treatment of Extra Risk."

TUESDAY, JANUARY 30 .. African Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5 p.m. Mr. T. A. Barns, "Ngorongoro, the Giant Crater; and the Gorilla, the Giant Ape."

Royal Institution, Albemarle Street, W 3 p.m. Mr. R. D. Oldham, "The Character and Cause of Earthquakes." (Lecture I.)

Photographic Society, 35, Russell Square, W.C., 7 p.m. Mr. T. Ball, "On the Thames with a Camera."

Roman Studies, Society for the Promotion of at the Society of Antiquaries, Burlington House, Piccadilly, W., 4.30 p.m. Mr. G. H. Hallam, "The Roman Forum."

University of London, King's College, Strand, W.C., 5.30 p.m. Rev. Percy Dearmer, "Sixteenth Century Art." (Lecture II.)

5.30 p.m. Miss H. D. Oakley, "The Enigma of Socrates." (Lecture II.)

5.30 p.m. Sir Bernard Pares, "Contemporary Russia from 1861." (Lecture II.)

WEDNESDAY, JANUARY 31 .. University of London, University College, Gower Street, W.C., 3 p.m. Professor E. G. Gardner, "Dante in his Works." (Lecture I.)

5 p.m. Professor Sir William Bragg, "Radioactivity and X-Rays." (Lecture I.).

5.30 p.m. Major C. Davenport, "Italian Book-binding."

University of London, King's College, Strand, W.C., 5.30 p.m. Sir Frank Dyson, "The Measurement of Stellar Distances."

Literature, Royal Society of, 2, Bloomsbury Square, W.C., 5 p.m.

British Academy, at the Royal Society, Burlington House, Piccadilly, W., 5 p.m. Dr. E. W. Scripture, "The Study of English Speech by New Methods of Phonetic Investigation."

Industrial League and Council, Caxton Hall, Westminster, S.W., 7.30 p.m. Sir Arthur R. Holbrook, "Industrial Liberty."

Public Health, Royal Institute of, 37, Russell Square, W.C., 4, p.m. Dr. A. L. Punch, "Laboratory Methods in the Investigation of Tuberculosis."

Civil Engineers, Institution of, Great George Street, S.W., 6 p.m. Mr. T. R. Wilton, "Foundations in Docks and Harbour Works. (Lecture II.)

THURSDAY, FEBRUARY 1 .. Aeronautical Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.30 p.m. Mr. G. S. Baker, "Ten Years Testing of Model Seaplanes."

Chadwick Public Lecture, at the Royal Institute of British Architects, 9, Conduit Street, W., 8 p.m. Mr. G. T. Forrest, "London's Unhealthy Areas."

Linnean Society, Burlington House, Piccadilly, W., 5 p.m.

Chemical Society, Burlington House, Piccadilly, W., 8 p.m.

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C., 6 p.m. Mr. P. J. Robinson, "The Maintenance of Voltage on a D.C. Distribution System by means of a Fully Automatic Substation."

University of London, University College, Gower Street, W.C., 5.15 p.m. Prof. J. E. G. de Montmorency, "The Distribution of Customary Law in England and France." (Lecture I.)

5.30. Mr. K. Struckmeyer, "Ugo Foscolo and Italian Romanticism."

5.30. Mr. J. Bjorkhagen, "Swedish Literature in the XVIII. Century." (Lecture I.)

At King's College, Strand, W.C., 5.30 p.m. Professor W. Barthold, "The Nomads of Central Asia." (Lecture III.)

5.30 p.m. Dr. O. Vocadlo, "Modern Czech Novelists." (Lecture II.)

At the London Hospital Medical College, Turner Street, Mile End, E., 4.30 p.m. Mr. W. A. M. Smart, "The Mathematical Basis of Physiological Problems." (Lecture III.)

Royal Institution, Albemarle Street, W., 3 p.m. Dr. J. M. Heilbron, "The Photosynthesis of Plant Products." (Lecture I.)

Auctioneers' and Estate Agents Institute, 34, Russell Square, W.C., 6.30 p.m. Mr. G. Mould, "The Law of Property Act in its relation to Estate Agents."

Mechanical Engineers, Institution of (North Western Branch), Memorial Hall, Albert Square, Manchester, 7 p.m. Mr. J. H. Hardman, "Mule Spinning Machinery."

Camera Club, 17, John Street, Adelphi, W.C., 8.15 p.m. Mr. J. E. Saunders, "Off the Beaten Track at the Zoo."

London County Council, at the Geffrye Museum, Kingsland Road, E., 7 p.m. Mr. C. A. Hindley, "The History of Chairs."

Dyers and Colorists, Society of (West Riding Section), Bradford, 7.15 p.m. Mr. H. P. Hird, "The Treatment of Coal for the Production of Smokeless Fuel, Motor Spirit and Fuel Oil."

FRIDAY, FEBRUARY 2 .. Royal Institution, Albemarle Street, W., 9 p.m. Mr. C. F. Cross, "Fact and Fantasy in Industrial Science."

Mechanical Engineers, Institntion of (Yorkshire Branch), Philosophical Hall, Park Row, Leeds, 7.30 p.m.

University of London, University College, Gower Street, W.C., 5.15 p.m. Professor R. Muir, "Bureaucracy."

At King's College, Strand, W.C., 5.30 p.m. Dr. R. W. Seton-Watson, "Serbia and the Jugo-Slav Movement." (Lecture III.)

Sanitary Institute, The University, Edmund Street, Birmingham, 7.30 p.m. Mr. J. Robertson, "Town and Country Milk Supplies."

SATURDAY, FEBRUARY 3 ... Royal Institution, Albemarle Street, 3 p.m. Mr. J. C. Squire, "Subject in Poetry." (Lecture I.)

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FRIDAY, FEBRUARY 2, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.(2)

NOTICES.

NEXT WEEK.

MONDAY, FEBRUARY 5th, at 8 p.m. (Cantor Lecture.) HENRY P. STEVENS, M.A., Ph.D., F.I.C., "The Vulcanisation of Rubber." (Lecture I.)

WEDNESDAY, FEBRUARY 7th, at 8 p.m. (Ordinary Meeting.) CHARLES R. DARLING, F.Inst.P., F.I.C., "Electrical Resistance Furnaces and their Uses." SIR ROBERT A. HADFIELD, BT., D.Sc., F.R.S., will preside.

Further particulars of the Society's meetings will be found at the end of this number.

EIGHTH ORDINARY MEETING.

WEDNESDAY, JANUARY 24TH, 1922; SIR FRANCIS GRANT OGILVIE, C.B., LL.D., Chairman of the Geological Survey Board, in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Amin, Bhailal Dajibhai, B.A., M.S.C.I., Baroda, India.
Coubrough, Anthony Cathcart, C.B.E., M.A., B.Sc., M.I.E.E., M.I.Mech.E., Calcutta, India.
Kitchell, Major Joseph Gray, New York City, U.S.A.
Thomson, James B., Vancouver, B.C., Canada.

The following candidates were balloted for and duly elected Fellows of the Society:

Bruford, Stanley John, Nepal.
Parker, William Rushton, M.A., M.D., London.
Wright, Frank Claude, A.M.I.Mech.E., London.

The Trueman Wood Lecture on "The New Methods of Crystal Analysis, and their bearing on Pure and Applied Science," by SIR WILLIAM HENRY BRAGG, K.B.E., M.A., D.Sc., F.R.S., Quain Professor of Physics, University of London, was, owing to the illness of Sir William Bragg, delivered by Mr. G. Shearer, M.A., B.Sc., Research Assistant, Physics Department, University College, London.

The lecture will be published in a subsequent number of the *Journal*.

INDIAN SECTION.

A meeting of the Indian Section Committee was held on Friday, January 19th. Present: Sir Edward A. Gait, K.C.S.I., C.I.E., Ph.D., in the chair; Sir George Stapylton Barnes, K.C.B., K.C.S.I., Sir Charles H. Bedford, LL.D., D.Sc., Mr. William Coldstream, B.A., Major-General Beresford Lovett, C.B., C.S.I., Mr. F. Noyce, C.B.E., I.C.S., and Mr. N. C. Sen, O.B.E., with Mr. S. Digby, C.I.E. (Secretary of the Indian and Dominions and Colonies Sections).

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

BROWN COALS AND LIGNITES.

By WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology.

LECTURE II.—*Delivered 4th December, 1922.*

INTRODUCTION.

Although immense deposits of easily-won brown coals and lignites occur in various parts of the world, the problem of utilising them is beset with difficulties arising out of their low-grade characters and particularly their high water contents. Also, before the war practically no brown coal technology had been developed except in Austria and Germany, with the result that other countries have had to build theirs up independently with little outside help. It will be my endeavour now to indicate the nature of the difficulties referred to and how they may be overcome.

First of all I would suggest that, from an economic standpoint, coal, in what we are pleased to call its "raw" state, is really a highly manufactured article. In its natural position in the bowels of the earth, its value as a marketable commodity does not exceed a few pence per ton; and in order to get it into a position where it is really valuable to mankind, a vast amount of human labour has to be expended upon it. I suppose, for instance, that a ton of coal lying unhewn in (say) a Yorkshire coal seam is not worth more to its owner than the present value of the small royalty which he will receive when it is won by the miner. Its value when it has been raised to the pithead will have been increased to (say) twenty shillings per ton; and when it has been further transported to the consumer's cellar in London, the price exacted for it will have increased to about forty shillings per ton. Hence, if values created by human labour and organisation are rightly to be considered as manufactured, the coal which we receive into our cellars here in London is undoubtedly a highly manufactured commodity.

Although such considerations may at first sight appear to be of purely academic interest, yet when viewed in their right perspective they may be shown to be of considerable importance. The economic value of coal in any given locality arises from the considerations (*a*) that it is a potential source of combustion-heat energy; and (*b*) that on carbonisation it is capable of yielding certain bye-products which are or may be of value in other connections. The relative importance of these two factors is largely dependent upon local circumstances, but always both of them must be taken into consideration.

Viewing the coal as a valuable commodity from these two points of view, the cost of delivering it to a would-be user in any particular locality is made up principally of three items, namely:—

(i.) winning the coal at the mine or other working;

(ii.) treating the raw product in any special manner so as either to enhance or concentrate its aforesaid values, or to separate them; and

(iii.) transporting it (or its concentrated or separated values) from the mine to the place of consumption.

Comparing the cases of brown coals and lignites with those of the older bituminous coals, it is obvious that whereas the former are much more easily won, because of their nearness to the surface, yet unless their fuel or bye-product yielding characters can be up-graded in some way, their transportation and use at a distance from the mine may be uneconomical. Indeed, in a general way, it may be said that, whereas in most countries the cost of winning the older black coals at the mine exceeds that of carbonising or "upgrading" them for any special purpose, yet the reverse is often the case with the newer brown coals which usually lie near the surface.

The chief difficulties associated with the utilisation of brown coals and lignites arise from the following circumstances, namely:—

(i.) their natural high water contents together with their tendency to disintegrate on being dried by any ordinary method;

(ii.) the fact that, owing to their low carbon and high oxygen contents, they have (even when completely dried) much lower calorific values and yield on carbonisation much higher proportions of "volatiles" than do bituminous coals.

Both these circumstances make it impossible to utilise them in the raw state with reasonable efficiency for steam-raising purposes in boilers, because so much heat is required to vaporise their natural water content that they do not give a sufficiently hot and radiating fire to ensure rapid heat transmission in boilers. Also, their high "volatile" yield means that they burn with a long and smoky flame which is not conducive to efficient working. Moreover, bad as is the natural high water content of raw lignites from a steam raising point of view, it is even worse from that of carbonising them for gas making under bye-product recovery conditions. It hardly needs an experienced gas engineer to realise the impracticability of carbonising, either in retorts or chambers, a raw coal containing anything from 20 to 50 per cent. of water, or to foresee the difficulties that would be encountered in attempting to recover tars and light oils from the steam-laden gas which would issue from the retorts. It is, therefore, obvious that any scheme for utilising such coals on a large scale ought to include some preliminary drying process. This may seem to be a very elementary

point, yet boilers are often fired with raw lignite, a practice which from every point of view is to be condemned.

The Drying of Brown Coals.

As an example of how much the mere drying of a brown coal will increase its effective calorific power for steam raising purposes in boilers, I will invite you to consider the following figures relating to the Morwell brown coal from Australia, which, in the raw state, contains about 50 per cent. of water. A given weight of raw coal would, therefore, be composed half of water and half of the dry coal. Now the *gross* heat of combustion of 0.50 Kg. of dry fuel is about 2,800 K.C.Us.; part of which, however, must necessarily be expended in vaporising the 0.50 Kg. of associated water, whilst another part would be rendered ineffective on account of the 0.225 Kg. of steam, which is formed when the fuel is burnt. These two items would amount altogether, to 445 K.C.Us., leaving only 2,355 K.C.Us. as the "effective" calorific power available for transmission to the water in the boiler. Thus it would appear that, taking into account the latent heats of the water present in the raw fuel and of that formed on its combustion, no more than 84 per cent. of its gross calorific value could possibly be "effective" in the boiler. And whereas, in the best of circumstances, no more than about 70 per cent. of such "effectively available" heat would actually be transmitted to the water in the boiler, and, therefore, finally appear as "available steam energy," it follows that no greater boiler efficiency than about 60 per cent. would be likely to be achieved by using the *raw* coal, and it would probably be considerably less.

The beneficial effects which might be expected to accrue from some preliminary drying (whether partial or complete) of such a raw fuel as Morwell Brown Coal are shewn by the following figures:—

Diagrammatically the case may be represented as follows:—

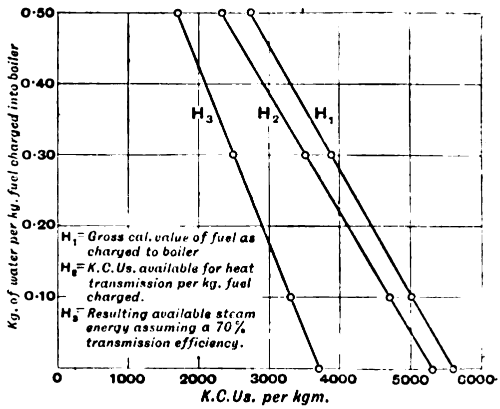


Fig. 4.

As to the means which are available for drying raw coals of such large water contents as we are now considering, a short reflection will make it clear that mere "air-drying" is not likely to be economical on a large scale, because it is far too slow and dependent upon climatic conditions. The rapidity of any air-drying operation of this kind, as well as the point to which it can be carried, depends upon the velocity of the air current and its hygroscopic state, as well as upon the temperature conditions. Thus in a relatively dry and warm climate like that of Australia, it has been found possible to air-dry brown coals down to a point at which they contain no more than about 16 per cent. of water, which means (assuming that the raw coal contains 50 per cent.) that more than four-fifths of the original water content can thus be removed. Experiments recently made upon such coals in our laboratories at South Kensington showed that in a current of air whose humidity varied between 62 and 79 per cent. of saturation with a draught velocity of 221 feet per minute, the water content of the lump coal could be reduced to between 16 and 20 per cent. in about 22 hours,

Composition of 1 Kg. Fuel charged into Boiler.		Gross Cal. value of Fuel as charged K.C.Us. per Kg.	K.C.Us. available for Heat Transmission per Kg. Fuel charged.	Resulting Available Steam Energy assuming a 70% Transmission Efficiency.	Ratio.
Water Kg.	Dry Coal Kg.	H_1.	H_2	H_3	H_3-H_1
0.50	0.50	2800	2355	1650	0.589
0.30	0.70	3920	3542	2480	0.633
0.10	0.90	5040	4730	3310	0.657
nil.	1.00	5600	5324	3725	0.665

whereas that of the same coal in a powdered state could be reduced to a little more than 11 per cent. in 18 hours. I might perhaps add, as showing the efficacy of an induced air-current for such drying operations that, during the month of September last, I attempted to air-dry a consignment of 182 pounds of raw brown coal containing 55 per cent. of moisture by spreading it out under cover in a thin layer on a concrete floor in an airy situation for a period of one month. At the end thereof, its weight was reduced to 133 pounds, which meant that only about half the original water content had been removed, and that the residue still contained about 37½ per cent. of water.

Various artificial methods have been resorted to for the drying of lignites, all of which depend upon the use either of :—

(*a*) hot combustion products ;
(*b*) hot air ; or
(*c*) steam in various forms of drying plant.

For a long time past the drying appliances used in the German brown coal industry have consisted almost exclusively of one or other of two types, namely ; (i.) what is known as the table oven type, in which the drying agent is either hot products of combustion or preferably steam, and (ii.) steam drum tube dryers. Those who may be interested in this aspect of the question may be referred to the information given in Vol. I of the latest English translation of G. Franke's well-known "Handbook on Briquetting" (Chas. Griffin & Co., 1916). The choice between the two types of appliances depends largely upon the nature of the coal. Thus a hard or sandy coal causes too much wear and tear of the table surfaces and plate shovels or stirrers in the table oven type of dryer, and therefore, for such coal a tube dryer is to be preferred. On the other hand, a soft coal can be much more easily worked in the table rather than in the tube dryer. There is said to be not much difference between the thermal efficiencies of the two types of plant, which under good working conditions may be as high as 75 per cent. The cost of installing and running tube dryers is considerably less than with the table type ; on the other hand, the drying operation as a whole can be better regulated and controlled in the latter type.

Anyone who attempts to dry brown coals or lignites by direct contact with hot air or hot furnace gases must remember that there is a great risk of their catching fire at temperatures above 200° C. in atmospheres containing anything like the normal proportion of oxygen, and also that mixtures of brown coal or lignite dust and air are easily inflamed and highly explosive. In my own experiments I have found it unsafe to expose lignites or brown coals in a partially dried condition at temperatures above their ignition points, which usually lie between 200° and 250° C., to furnace gases containing less than about ten per cent. of carbon dioxide or more than about a like percentage of oxygen ; but, as a rule, furnace gases containing more carbon dioxide and less oxygen than the aforesaid limits may be employed with safety for drying operations at even higher temperatures. In any case, in constructing or installing appliances for drying brown coals at such temperatures, great care must be taken to exclude the possibility of air accidentally getting into them during drying operations.

It should also be remembered that a completely dried brown coal or lignite is very hydroscopic and will readily pick up and absorb water vapour from a moist atmosphere. For many purposes, such as briquetting, it is sufficient to dry the raw fuel down to a point at which it contains about fifteen per cent. of water ; but if the fuel is being prepared for subsequent carbonisation, a more complete drying is, for obvious reasons, advisable.

Heat Treatment at Temperatures Below 400° C. as a Possible Method of Enhancing their Fuel Values.

In the course of my researches upon brown coals and lignites, I had occasion to study their behaviour when, after being previously completely dried at 110° C., they were further heated, out of contact with air, in a special form of apparatus which permitted both an easy control of the temperature and the accurate measurement of any liquid or gaseous products that might be evolved.

In my first experiments on such lines, which were made upon the Morwell brown coal, some highly significant observations were made, which subsequent research has proved to be characteristic of brown

coals and lignites generally. The detailed results of these researches having already been published about a year ago in the proceedings of the Royal Society, A. Vol. 99 (1921), I need now describe them in outline only.

It was found with the dried Morwell coal that, beginning at as low a temperature as 130° C., but principally between 250° and 375° C., a chemical condensation occurred, affecting the cellulosic or humic constituents, which was characterised by the simultaneous elimination of both steam and carbon dioxide from the coal substance itself, without any appearance

	Dry Coal. treated.	Residual Coal.
Carbon	62.50	68.5
Hydrogen	4.85	4.9
N. and S.	0.65	0.8
Oxygen	28.00	21.2
Ash	4.00	4.6
	100.00	100.00
Gross Calorific Value K.C.Us. per Kg.	5600	6360

The chemical and thermal balances of the experiment were as follows :—

	100 Parts of the dry coal containing Parts	→ yielded →	87.6 Parts of Residual Coal containing :— Parts.
Carbon	62.50	5.5 H_2O 6.5 CO_2	60.00
Hydrogen	4.85		4.30
Oxygen	28.00		18.55
K.C.Us. ..	560.000		558.000

of oils or more than a quite negligible amount of gaseous hydrocarbons. Thus, in a typical experiment, when the temperature of 100 parts by weight of the dried coal was slowly raised to, and then maintained at 375° C., until no further change occurred, there were eliminated 5.5 parts of water and 6.6 parts by weight of gas (= 1427 cub. ft. per ton of the dry coal), which latter contained :—

$H_2S = 1.5$, $CO_2 = 88.5$, $CO = 4.1$, $CH_4 = 1.1$ and $N_2 = 4.8$ per cent.

It was thus clear that the said heat treatment had brought about a chemical condensation in the coal substance itself, possibly comparable with that by which, deep down in the bowels of the earth, our present bituminous coals, in the course of long ages, have been slowly produced from pre-existing brown coals. Such condensations had involved a marked elimination of oxygen (as both steam and carbon dioxide) from the coal substance, with consequent considerable weight loss (amounting to one-eighth of the original) and marked increases both in the percentage of carbon content and calorific value.

The percentage composition and calorific value of the dry coal treated, and of the "residual coal" obtained were as follows :—

It will thus be seen that whilst the dry coal had lost about one-eighth of its original weight, it had retained practically the whole of its potential heating power, but in a more concentrated form. The weight loss had amounted to about one-third of the oxygen, one-tenth of the hydrogen, but only one-thirtieth of the carbon originally present in the coal substance—a very remarkable result.

Subsequent research showed that a similar behaviour on heat treatment is characteristic of brown coals and lignites generally, and may be used as a means of upgrading them and improving their fuel values. Indeed, the following conclusions may be accepted as having been already sufficiently well-proven, experimentally, to justify their adoption in practice, namely :—

(i.) that there is for each particular lignite a certain definite temperature limit (usually between 300° C. and 400° C.) up to which it may be heated in the dry state so as to effect a considerable chemical condensation in its cellulosic or humic constituents, with simultaneous expulsion therefrom of steam and carbon dioxide, together with a small but variable proportion of carbonic oxide;

(ii.) that the said chemical condensation

is unaccompanied, within the temperature range in question, by any other change productive of either hydrogen or hydrocarbons;

(iii.) that the consequent loss in weight experienced by the "dry ashless" coal substance up to the temperature limit in question may amount to anything between 8 and 15 per cent. of its original weight;

(iv.) that such loss in weight occurs principally at the expense of the oxygen content of the dry coal, which is diminished by between one-quarter and one-third of its original value;

(v.) that in the said manner substantially the whole of the potential energy of the fuel may be concentrated in the resulting carbonaceous residue, which may, therefore, be burnt with greater calorific intensity than the original coal; and

(vi.) that, accordingly, such treatment constitutes a possible means of "up-grading" brown coals and lignites generally, thereby improving their fuel values.

Having already explained the effect of such heat treatment upon the Morwell brown coal, which may be taken as a typical earthy brown coal of fairly recent origin, I will now give you some further particulars as to the average behaviour of a more mature lignite, such as those occurring in Saskatchewan. In this case I found that the temperature limit to which the dry coal could be heated without loss of either oils or hydrocarbon gases was 350° C., and that up to such degree 100 parts by weight of the dried coal lost 4.5 parts by weight of water and 4.5 parts by weight of gas, or a total of 9 parts by weight altogether. The gas evolved amounted to about 900 cubic feet measured at N.T.P. per ton, and it contained 73 per cent. of carbon dioxide, 25 per cent. of carbon monoxide and 2 per cent. of nitrogen. The average balance sheet for the experimental treatment was as follows:—

AVERAGE RESULTS OF HEAT TREATMENT OF DRY SASKATCHEWAN LIGNITES UP TO 350° C.

	100 parts of the dry coal containing	→ yielded →	91 parts of residual coal containing
	Parts.	4.5 gas 4.5 H_2O	Parts.
Carbon ..	63.25		62.0
Hydrogen ..	4.35		3.7
Oxygen ..	22.20		15.6
K.C.Us.	586,000		576.000

Gas evolved = About 900 Cub. Ft. at N.T.P. per ton containing $CO_2 = 73.0$, $CO = 25.0$, $N_2 = 3.0$ per cent., whilst the compositions of the original coal and the concentrated residues derived therefrom was as follows:

EFFECT OF HEAT TREATMENT ON SASKATCHEWAN LIGNITES.

	Dry Coals.	Residual Coals.
	%	%
Carbon	61.6 to 64.5	67.5 to 68.4
Hydrogen	4.2 to 4.7	3.5 to 4.4
N & S.	1.2 to 1.9	1.4 to 2.1
Oxygen	20.5 to 24.7	14.4 to 19.3
Ash	6.1 to 11.2	6.9 to 12.7

It will thus be seen that by such heat treatment the dry coals lost about one-fiftieth part of their original carbon (as CO_2 and CO in the ratio of about 3 to 1 by volume), between one-sixth and one-seventh part of their original hydrogen (as steam), and as much as 30 per cent. of their original oxygen, but retained more than 98 per cent. of their potential energy in the residual concentrated fuel.

At one time I was inclined to think that the degree of maturity of a particular coal can be gauged by the CO_2/CO ratio in the gases evolved during the process, but further experiments have thrown some doubt upon this suggestion. That this

ratio varies considerably with brown coals and lignites of different origins is a fact which has been well established by experiment, but what its precise meaning is I do not at present profess to know, except that it seems to me to be rather suggestive of some chemical difference in the humic constituents of the various coals. The following table will give some idea of how considerably the ratio in question may vary in different cases :—

COMPOSITION OF GAS OBTAINED BY THE HEAT TREATMENT OF BROWN COALS AND LIGNITES.

	1 Morwell Brown Coal.	2 Valdarno Lignites.	3 Saskatchewan Lignites.	4 Burmese Lignites.
Temperature up to	375°	300° to 320°	320° to 360°	320°
Cub. Ft. per ton	1427	780 to 810	810 to 940	800
	%	%	%	%
CO_2 (H_2S)	90.0	75 to 85	70 to 75	83.2
CO	4.1	10 to 21	20 to 30	11.4
CH_4	1.1	0.3 to 1.3	nil	nil
H_2	nil	nil	nil	nil
N_2	4.8	4.0	1 to 3	5.4
	100.0			100.0

does not allow of my dealing with the subject as fully as its importance merits, but I will endeavour to indicate to you some of the salient points about the commercial briquetting of brown coals and lignites and the carbonised or semi-carbonised residues obtainable from them.

The best procedure and methods to be adopted will depend to some extent on whether the material to be dealt with is (i.) the raw untreated coal, or (ii.) a residue

The Briquetting of Brown Coals and Lignites.

Although properly dried brown coals and lignites are often utilised *in situ* for steam raising or carbonising purposes, yet in cases where the coal has to be transported for some distance either for domestic or steam raising purposes, it is usual to briquette it at the mine. During the past 50 years or more, the briquetting of brown coals has become a highly developed industry in both Germany and Austria, where the resulting briquettes are largely used both as domestic and industrial fuels. So much so that there seems to be a general impression that only in these countries can the briquetting problem be effectively studied. I can, however, assure you that there are firms in this country who have given particular attention to the problem, and who are quite capable, not only of determining the best conditions for the briquetting of any particular brown coal or lignite, but also of supplying the type of machinery required for the purpose. The time at my disposal

which has been previously dried and "upgraded" in the manner referred to in the preceding section of my lecture, or (iii.) the residue produced by either partially or completely carbonising a dried lignite.

If the material to be dealt with is the raw coal produced at the mine, it must first of all be crushed and then dried down to a suitable degree. As to the latter, it may be said that the amount of moisture which it is advisable to leave in a brown coal in order to secure briquettes of the best quality may vary according to the character of the same from 10 up to even 25 per cent., but that in most cases something between 15 and 20 per cent. will be found advisable. The water so remaining in the coal, all of which may be expelled at 100° C., materially assists in the subsequent briquetting operations by increasing the cohesion of the coal particles during the pressure.

The next point to be decided is whether or not to use a binder in the briquetting process ; and as there is a good deal of misunderstanding about this point, I may,

perhaps, be allowed to explain its significance. It may be said at once that there are some brown coals (and particularly those found in Germany) with properties such that they can be successfully briquetted on a commercial basis without the addition of any binding agent at all, provided that a sufficient degree of pressure is employed in the briquetting machine. Thus, in most of the German brown coal factories binding agents are not admixed with the coal. In such cases, however, the capital expenditure upon plant for a given output of briquettes is far greater than it would be if a binding agent were used in conjunction with lower working pressures. It is not, however, all brown coals and lignites that can be briquetted without binding agents, and even in cases where such procedure is technically possible, it becomes a question whether the interest and depreciation upon the necessarily higher capital outlay for plant is less than the cost of the binder thereby dispensed with. Whichever system, however, is adopted in any particular case, the coal must be delivered to the briquetting machine with a suitable moisture content, in a uniformly fine state of division, and at a proper temperature. The maintenance of *uniform* conditions in all these respects is essential to successful working.

The usual methods practised in Germany may be epitomised as follows. The briquetting factory is usually built in close proximity to the mine. The raw coal is first of all submitted to mechanical crushing, grinding, and sieving operations, in order to get it into the desired state of sub-division for the particular type of briquettes subsequently to be made. It is next passed on to the drying plant, where it is dried down to the degree requisite for the production of good briquettes; as a rule, a water content of between 12 and 17 per cent. is considered to be the best. In order to produce the best quality of briquettes, and especially those intended for domestic consumption, the partly dried coals are thoroughly mixed in order to equalise variations in their moisture contents and temperatures so as to ensure uniformity of material at the briquetting machine. Also, it is considered essential that the resulting material shall be cooled down to a uniform temperature usually between 30° and 40° C. It is finally briquetted in a steam driven press, where the coal is pushed and compressed by the stroke of the press stamp into a mould of suitable section, whence it is extruded against a rope of previously compressed briquettes moving outwards. Most of the newer presses installed are of the two-stroke type, with two equal pressing moulds, one on each side of the driving shaft, and they run at from 130 to 140 revolutions per minute, compressing the material up to an end pressure of 1200 to 1500 atmospheres (or say between 8 and 10 tons per square inch). One of the latest types of German presses is shewn in the accompanying photograph (Fig. 5).

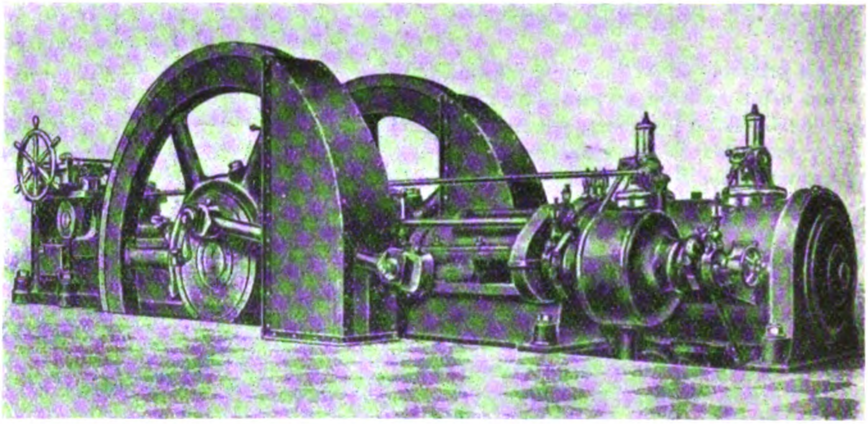


Fig. 5.

In cases where either the nature of the coal demands it, or a smaller proportionate capital outlay than that required for the German system is desired, a suitable binder must be employed. Various substances have been tried for this purpose, but so far coal tar pitch is by far the best known, because,

(*a*) it helps the coal to burn,
(*b*) it adds practically no ash, and
(*c*) the briquettes agglomerated with it are very hard and quite weatherproof.

The best quality to use for the purpose is the "medium" and it should contain only 0.25 to 0.5 per cent. of ash. The pitch is broken up small and fed, along with the coal, into a mixer for measuring accurately the proper proportions of the two materials, which then fall into a disintegrator, where they are ground together to the proper degree of fineness. This ground material (coal and pitch) is then elevated and delivered into a vertical heater, where, in its downward passage through the same, it is subjected to the action of superheated steam at a suitable temperature, by means of which the pitch becomes plastic and adhesive. This heater is fixed over the briquette press which is fitted with a vertical mould plate with intermittent motion, having usually eight moulds in it. At each stroke of the machine the plastic material is pushed by a horizontal ram into one of the moulds. When the full mould reaches the opposite side, the material is powerfully compressed from both sides simultaneously by two rams working horizontally. A fourth ram pushes out the finished compressed blocks, which are then conveyed to the stacking yard or loaded into trucks. A briquetting press for producing such rectangular briquettes is shewn in Fig 6.

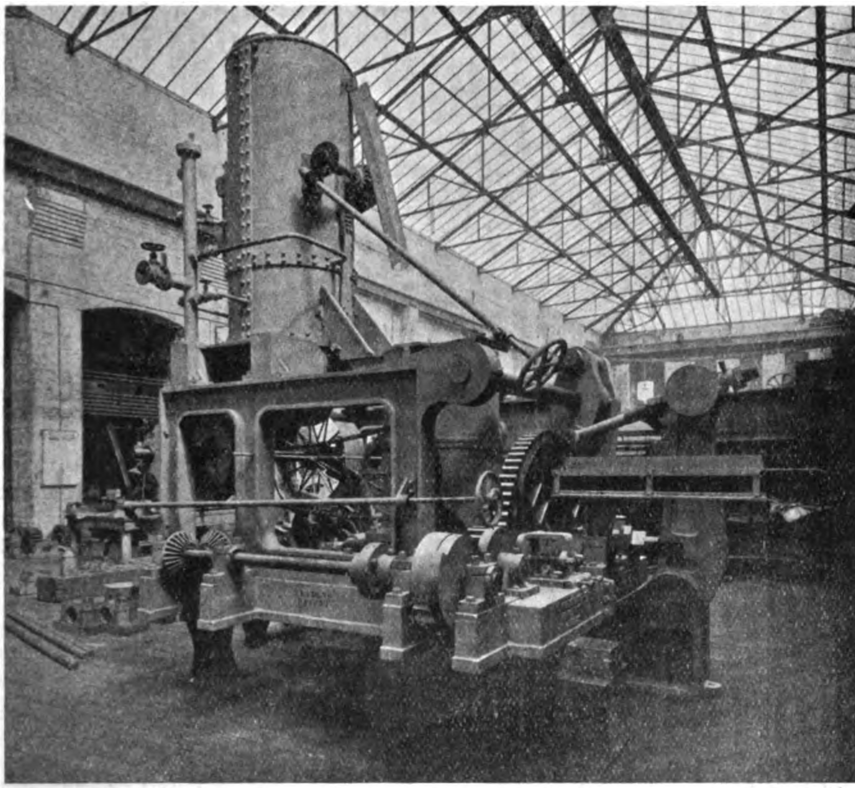


Fig. 6.

This double compression—*i.e.*, pressure of the briquettes from both sides simultaneously—has been found to be a great improvement on the single pressure from one side only, the briquettes being of a more regular density throughout. The moulds are shaped to produce briquettes with rounded corners, and with the system of double compression another important improvement has been introduced with these presses by which the edges on both faces of the briquettes are also rounded, thus largely minimising breakage in transit. Such a procedure produces rectangular forms of briquettes with rounded corners and edges; and they can be made in

different sizes varying from 2 lbs. to 24 lbs. each.

For many purposes, however, ovoid briquettes are to be preferred to the rectangular form. The manufacture of these is carried out on much the foregoing principles, except that in the machine employed for compressing the coal (Fig 7.)

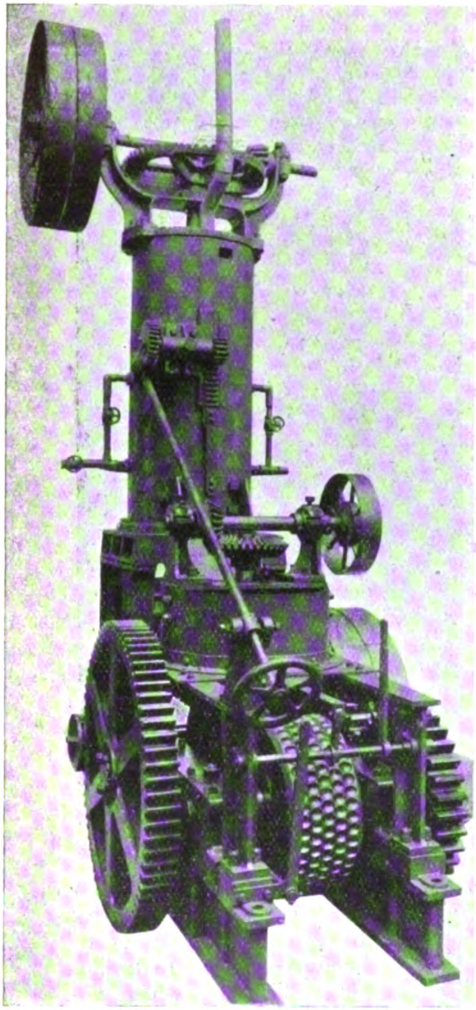


Fig. 7

the material passes between two rollers on the perimeters of which are rows of ovoid cavities which face one another when the rollers are working, thereby producing briquettes of ovoid shape under a pressure of two tons per square inch. Such ovoid briquettes can be made in sizes varying from that of a walnut up to that of a hen's egg, and are most suitable for domestic and steam-raising purposes. In Fig. 8 is shewn a briquetting factory with an ovoid press at work.

Unfortunately, however, the supply of coal tar pitch is limited, and its rapidly rising cost (now exceeding £5 per ton) is becoming a serious item in regard to the manufacture of briquettes. The minimum amount of pitch required to produce satisfactory results varies according to the nature of the coal between, say, about 5 and 10 per cent. of the weight of the finished product, and its regular supply in the localities where the brown coals are found is often a matter of difficulty, necessitating the trial of substituting materials. In some cases the pitch-like residues from the distillation of petroleum oils have been successfully employed, and in my experience, such materials are practically as good as coal tar pitch for the purpose. In countries with a dry, warm climate, such binding agents as rice, maize meal, farrino or potato starch, along with a small percentage of lime can be used. In corn producing countries, the offals from either rice or maize meal, which can easily be obtained at small cost, may be ground up to the consistency of flour, and then used as an agglomerant in the proportion of between two and three per cent. of the meal and two and two and a half per cent. of lime. In all such cases, however, the resulting briquettes have the disadvantage of not standing exposure to wet weather.

It has already been said that briquetting processes are applicable not only to the original coal, but also to the carbonaceous residues obtained when it is either upgraded by moderate heat treatment or carbonised. In the case of carbonised residues, however, the use of some binder is in my experience essential, and there is none better than pitch derived either from coal tar or petroleum distillation. Such pitch in proper admixture with the carbonised residue up to a proportion between about 7 and 10 per cent. of the whole, will produce a firm briquette which in a short time after its manufacture hardens considerably and will then stand transport by rail or ship. Small ovoid briquettes so manufactured make an excellent boiler fuel, expecially for chain brake furnaces, and they burn almost smokelessly. Indeed, if the manufacture of briquettes from carbonised residues be combined with the low temperature distillation processes of the raw coal after it has been considerably dried, not only can

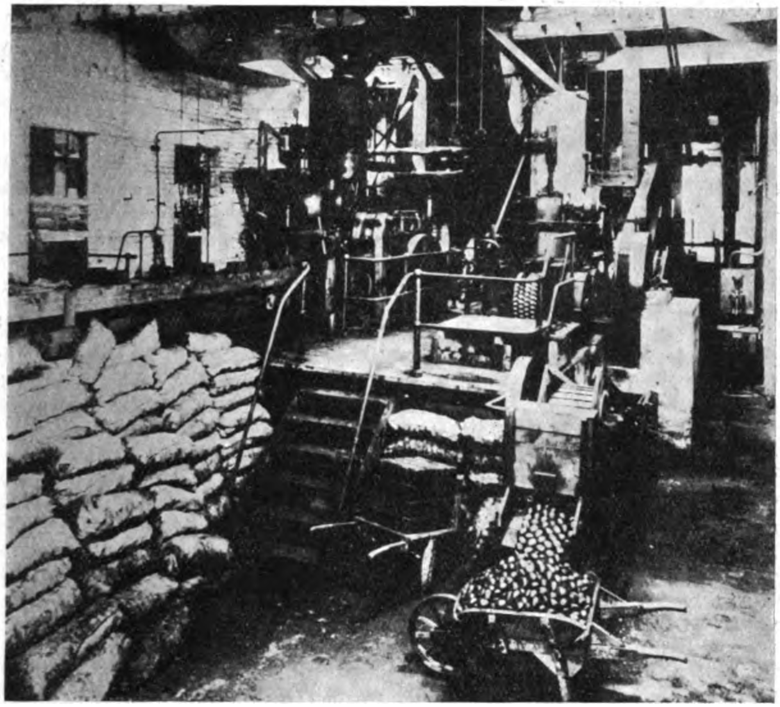


FIG. 8.

valuable oils be obtained, but also a practically smokeless solid fuel can be produced which in a small ovoid form is excellent for steam-raising.

In concluding these observations upon briquetting processes, I perhaps ought again to emphasise the importance of precautions being taken against the formation in the factory of explosive admixtures of brown coal dust and air. The fact that in Franke's well-known treatise upon briquetting, to which reference has already been made, an entire section is devoted to the subject of the danger from coal dust fires and explosions in briquetting factories, may be taken as an indication that in Germany at least such dangers are fully realised. Undoubtedly, the dry flour-fine coal dust produced during the grinding and drying operations is not only a nuisance but also a considerable source of danger in all brown coal briquetting operations. Its danger to life and property depends upon the fact that it is not only very easily ignited, but also that when once ignited disastrous fires and explosions may result. In the early days of the brown coal briquetting industry in Germany, quite a number of such explosions occurred in the factories, and recent years have not been entirely free from them. In the years 1899-1890, Dr. Rudolph Holtzwort and Professor Ernst von Meyer investigated the cause of explosions in the Saxon brown coal briquette factories. They reported (i) that the first and only dangerous agent in a brown coal briquette factory is the fine dry coal dust when it becomes widely disseminated in air; (ii) that the primary cause of an explosion is usually the origination of a local fire of glowing coal dust; and (iii) that such brown coal dust is very liable to undergo smouldering combustion in a slow current of air. It has been repeatedly demonstrated that even a comparatively small ignition of such glowing coal dust when whirled about in air is capable of rapid self-propagation and development into a disastrous explosion, if sufficiently supported by the presence of fine dust spread over large areas subjected to the free access of air. In this connexion it may be recalled that a violent explosion which occurred at the Saxonia factory at Zeisholz in Upper Lausitz in March, 1913, was afterwards found to have originated in the storeroom from an insignificant fire which was probably ignited by an electric spark.

CORRESPONDENCE.

THE ECONOMY OF SMOKE ABATEMENT.

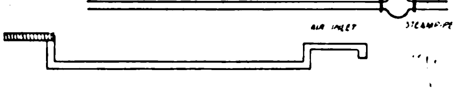
In reading the *Journal* of the Society dated December 22nd, 1922, I was surprised to note that the main cause of the smoke nuisance in cities, was not brought into any prominence. In the central part of this country soft coal is used to feed boilers in all manufacturing establishments. The air is polluted with fine soot, and the atmosphere is most disagreeable in consequence. When I was operating my factory in 1881, I had settled the question with such success that for two years prior to the destruction of my factory by fire, no smoke came from the furnace heating my boilers, producing steam to operate the plant: although previous to the use of my invention, a sketch of which I enclose, my smoke stack had been doing its full share in belching forth black smoke.

The Boiler was sixty inches in diameter, twenty feet long and above the water line, supplied with three inch tubes. Before the application of my invention my coal bill averaged one hundred and twenty five dollars each month. After the boiler front to the furnace had been furnished with five or six air injectors, like those shown in the sketch, when doing the same work in the factory the cost of coal averaged ninety-five to ninety-seven dollars each month. Every morning before steam was supplied to the air injectors, a column of black smoke issued from the smoke stack. The moment the first supply of air came to the fire from the injectors, the black smoke from the smoke stack disappeared, and product of combustion of the coal was about what a wood fire would show. I did not patent my invention.

This information may be of interest in connection with the paper read at your meeting.

JOHN RING.

508, Merchants' Exchange,
St. Louis,
U.S.A.



This fitting, to be screwed into each boiler front, in spaces six or eight inches apart, acts as an injector to furnish air enough to complete the combustion of coal, making of the coal a smokeless fuel. The air coming in through it is thrown down on the burning coal. The steam supply is very small, being 1/64 of an inch, opening to each air inlet of fitting, 4 inches inside diameter.

ARGHAN.

Mr. G. A. Lowry sends some further particulars about Arghan, in continuation of his letter which appeared in the *Journal* of January 5th, 1923 (pages 137-8):—

THE FIBRE.—This fibre has been known and woven for many centuries. In the Philippines they take it from the leaves of the cultivated pineapple and call the fabric Pina Cloth.

In Colombia they wrapped their mummies in fibre taken from the wild pineapple, the robes of their Emperors were woven from it (some of them now in the Museum in Botoga). they used it for their bow strings, their lariats, their fish nets and hammocks (the latter so fine they could be carried in the pocket): in fact, it was used for everything requiring strength and pliability.

It has plenty of natural twist for spinning and no difficulty has been experienced in that direction with the flax spinning machinery. It has not been adapted to cotton spinning machinery and that may not be possible, but it has been woven with cotton and its unusual brilliancy makes a beautiful fabric.

One of the largest rope works in the United States has declared their intention of putting up a special mill as soon as they can be assured of a permanent supply, and there are already many enquiries for the yarn.

THE SUPPLY OF RAW MATERIAL.—The writer's attention was first drawn to this wild growth by the efforts of a Colombian to dispose of 50,000 acres in the Province of Bolivar to some New York gentlemen. On investigation, they found the entire tract was densely covered with Pita Floja, and, therefore, useless, as the land was not worth the cost of clearing it and there was no mechanism for reducing the pestiferous growth to fibre.

These New York gentlemen, however, had some leaves sent up and submitted to an American inventor, who successfully decorticated it. A syndicate was then formed to investigate the extent of the growth in Colombia, and the writer spent six months there as one of these investigators.

It was impossible to penetrate the forests where the Pita Floja grew because of their density and the sharp hook shaped thorns on their edges, but by travelling up the beds of dry streams in one direction and of other streams running at right angles, and gauging from maps the distance between, it is safe to say that in the Province of Magdalena alone there is one hundred miles square (not one hundred square miles) of Pita Floja.

Mr. Marshall, the representative of the United Fruit Co., at Santa Marta, who had carried extensive surveys into that country, confirmed this estimate.

Mr. T. Dawe, the English head of the Colombia Agricultural Department, reports there are even greater tracts up the Opon River, and

informants from the Ortrato Valley claim an even more voluminous supply there. We have also authentic reports of its extensive existence in Southern Mexico, Guatemala, Honduras, Nicaragua, Costa Rica, Panama, Ecquador, Venezuela, the Guianas, Peru and Brazil.

As it is not to be found on the trade routes it does not come under the observation of the usual traveller, but is obnoxiously known to the prospector and the hunter because of its impenetrability.

The New York Corporation, who recently imported the leaves for the botanists to classify, expect to continue their investigations and surveys shortly in these other tropical republics.

The Arghan Company has about sixty acres planted in the Federated Malay States, and the British Government is offering inducements for the extending of that territory. The original plants were transplanted from British Honduras by Sir Henry Wickham, but only a small percentage survived the trip across two oceans. The increased growth must come from suckers, as the plants do not form seeds, and, therefore, cannot increase very rapidly; so that supply is not likely to affect the market for many years.

Decorticating the Plants.—Until the advent of a machine by an American inventor, reported by the United States Vice-Consul at Barranquilla, April 4th, 1921, there has been no known mechanism for cleaning the fibre.

Many unsuccessful attempts had been made with sisal machinery and a few abortive attempts by other inventors, but all by cumbersome machinery, which is not feasible in a country where there are no roads and everything must be carried pack saddle fashion. That is one of the great drawbacks to sisal machinery. Ordinary plants, to take 100,000 leaves daily, require $125,000.000 to set up and operate and they are necessarily long distances apart. A great part of the supply will have to come from a radius of ten miles, so it is easy to see that when a mule makes a twenty mile round trip, carrying in four hundred pounds of leaves and bringing back sixteen pounds of fibre, he has not much to show for his effort. These sisal plants must have a house to cover them, fuel and water to run them and an executive to look after details.

The machine, which will be successful in the tropics must be portable by pack saddle, it must not be over two hundred pounds, and it must be operated singly by hand or foot power or in groups by rotary sweep horse powers or animal tread mills. The gasoline motor is beyond the intelligence of the natives in those outlying districts, and fuel, and particularly water, are hard to get. The ideal machine must be fool proof and require the lowest modicum of intelligence to operate it and be of the agricultural type, requiring no housing and either portable or easily movable so it can follow the growth, if necessary; though in single units the rapidity of reproduction of these plants would keep it supplied from a small radius.

Probable Cost of Production.—This may be fairly well arrived at by comparing it with sisal which grows in the same territory with about the same labour and other conditions, except that sisal has to be cultivated and has an expensive plant to upkeep, while Pita Floja grows wild and has no expensive instalments or overhead costs; and although sisal yields four per cent. of fibre against half that yield by Pita Floja, it is safe to say the cost of production of the latter cannot much exceed that of sisal, while its comparative market value would be at least twice that of sisal—take for instance in binder twine :—

1 lb. of sisal	yields	500	feet of binder twine
1lb. of manila	,,	650	,, ,, ,,
1 lb. of pita floja	,,	980	,, ,, ,,

It is not at all probable, however, that this fibre will ever have to compete with sisal or manila. It is more likely to go into seine twine, shoe thread and fabrics.

The Market.—Admitting this fibre is in the flax class, there is a tremendous shortage. Russia raised 730,000 tons of flax in 1915; at present not one-third of that is now raised there. France, Belgium, Ireland and Hungary have also fallen far below their original production, so the opening is greater than is likely to be met in several years even if the New York Corporation succeeds in putting out one hundred machines weekly, for the capacity of these machines, according to the consular report, does not exceed one hundred pounds each of dry fibre per day. It would take a thousand of such machines to produce twelve hundred and fifty tons monthly and four times that amount to make any impression on the market.

G. A. Lowry.

OBITUARY.

The Hon. Richard Clere Parsons, M.A.—Many Fellows of the Society will learn with much regret of the death of the Hon. Richard Clere Parsons, which took place on January 26th, after a short illness, in his seventy-second year. Mr. Parsons joined the Royal Society of Arts in 1892. In 1900 he was elected a member of the Council, and he continued to serve on it with one or two short breaks until 1921, when ill-health compelled him to resign. He took a deep interest in the work of the Society; in 1909 he read a paper before it on "Improvements in Resilient Wheels for Vehicles;" he presided at numerous meetings and frequently took part in the discussions.

Born in 1851, the third son of the third Earl of Rosse, Mr. Parsons was educated at Trinity College, Dublin, where he was Senior Moderator and Gold Medallist in Physical Science and

Chemistry. He stood as Independent Conservative candidate for the University of Dublin in 1887, but was defeated. He became a partner in the firm of Messrs. Kitson & Co., Leeds, and took an active part in the development of the Yorkshire College, now the University of Leeds. Later on he entered into partnership with Mr. J. F. La Trobe Bateman, F.R.S.

For two years (1893-5) Mr. Parsons was Engineer to the Irish Congested Board; but a great deal of his practice was carried on abroad. Among other works he superintended the design and construction of the water and drainage system of Buenos Ayres, and he prepared plans for a drainage system for the city of Petrograd. He was awarded by the Institution of Civil Engineers a Telford Gold Medal, a Manby Premium, and a Millar Scholarship for researches in connexion with centrifugal pumps. Always keenly interested in education he was Treasurer and Deputy Chairman of the Delegacy of King's College, London, and a Governor of the Imperial College of Science and Technology. He also contributed numerous papers to scientific societies.

SERICULTURE IN CZECHO-SLOVAKIA.

The Association for Silkworm Culture recently formed in Czecho-Slovakia has done its best to extend sericulture in that country and has received the support of one of the great landed proprietors, who has had mulberry trees planted in his extensive gardens. From these trees, young plants have been distributed by the association to the cultivators. During the autumn of 1921, 10,000 plants were thus distributed, and in 1922 about 1,000,000.

According to a report by the United States Assistant Trade Commissioner at Prague, there are at present in Czecho-Slovakia more than 3,000 silkworm cultivators, and the number of silkworms is estimated at 20,000,000. The entire industry is in the hands of the association, which partly defrays expenses for the annual dues of 5 crowns per member and receives Government assistance through the Ministry of Agriculture in the following ways:—

1. The Government supplies the eggs, which are distributed free of charge to the members of the association.
2. It reimburses the association to the extent of 1 crown for each mulberry plant given gratis to schools or poor people. This is to encourage a broad distribution of young plants.
3. The Government pays to the association from 3,000 to 5,000 crowns per year to cover the expenses of correspondence.

The association, which has been operating for only two years, and is a non-profit making body, has established a silk-spinning mill further to facilitate development of agriculture. The cocoons are brought from the cultivators (at 70 crowns per kilo), spun into yarn, and the yarn sold to the weaving mills, of which there are several in Czecho-Slovakia. The net profits of the association's spinning mill are divided among the cultivators as a premium.

The weaving mills have been buying their raw silk from abroad. In 1920 the Czecho-Slovak Republic imported 595,000 kilos of raw silk (kilo—2.2046 pounds). It is hoped, however, so to develop the native industry that a sufficient supply of raw silk will be produced so that not only the domestic demand can be met, but an export trade in silk yarns can be developed.

The harvest this year has been estimated at 8 metric tons of cocoons for Bohemia, Moravia, and Silesia, and 20 metric tons for Slovakia and Ruthenia. The silk produced in Czecho-Slovakia is very strong and the cocoons are often unusually large. A French scientist has declared that the fibre is stronger than that of the Italian silk and explains this by the fact that the mulberry leaves in Czecho-Slovakia develope more slowly and consequently possess a larger quantity of nutritive substance on which the silkworms feed. The climate is considered ideal for sericulture, and infectious diseases such as are found in Italy have not yet been experienced.

RADIUM PRODUCTION IN CZECHO-SLOVAKIA.

There is a large radium content in the uranium ore found at Jachymov, in Bohemia, near the frontiers of Saxony. Although the radium production in the United States is greater as to quantity, the ores of Jachymov are richer in quality. According to a report by the United States Trade Commissioner at Prague, the known supply of radium in the Jachymov district will last for 20 years, at the present rate of production. As there are three large mines which are not yet prospected as to depth, and in which the veins of ore widen as they are followed deeper it is certain, he says, that the mining of radium will continue for much more than 20 years at Jachymov.

The Jachymov mines passed in 1912 into the possession of the Austro-Hungarian Government. They have now become the property of the Czecho-Slovak Republic. The annual quantity or radium produced amounts to about two grammes. The net profits to the Government in 1913 were about 1,000,000 crowns. As the earnings from the radium mines of the Republic are looked upon as a possible source of much profit to the Government, projects are under way for electrifying the shafts and millhouses, as well as enlarging and modernising the entire plant. At present the equipment at Jachymov is somewhat primitive.

There are several by-products of considerable importance, among them being uranium dyes. A radio-active watering place is also being built in the vicinity of the mines.

THE WINE INDUSTRY OF PALESTINE

Although wine making is an ancient industry in Palestine, the present commercial industry has been built up during the last 35 years by Jewish colonists in Palestine. The Palestine vineyards are healthy and withstand diseases well. The Jewish colony at Rishon-le-Zion is the centre of the industry, but considerable quantities of wine grapes are grown at the colonies of Zichron Jacob, Rehovoth, Petach Tickvah, and Katra, and the German colony at Sarona.

According to a report by the United States Consul at Jerusalem, the vineyards utilized in the wine industry (300 to 400 acres) are practically all on the Plain of Sharon and mostly in the Province of Judea. Grapes for eating purposes grow in all parts of the country, and there is a considerable area in Transjordania devoted to the growing of raisin grapes, or sultanas. The wine-grape vineyards receive no rainfall during the growing and bearing season and are not irrigated, there being always a sufficient supply of sub-surface water.

Most of the wine grapes of the Jewish colonies are pressed at Rishon-le-Zion. The German colony of Sarona, near Jaffa, formerly produced considerable wine, but the industry was closed by the war. The wine-grape harvest begins about July 18th and lasts for about six weeks, the earlier grapes being used for dry wines and the last and ripe ones for sweet wines.

About 80 per cent. of the production is of the dry, red claret wines; eight to ten per cent. of white dry wines; eight per cent. of red sweet wines; and about two per cent. of white sweet wines. An average of about 6,600 gallons of cognac is distilled in normal years from the wine at Rishon-le-Zion. From 13,000 to 15,000 pounds of tartar are obtained per season. The stems and residue from the press are used for fertilising purposes.

The exports of wine during the year ended 31st March, 1921, amounted to 278,427 gallons, as compared with 302,465 gallons in the preceding year, but these figures do not include, it is thought, the entire amount sent overland to Damascus and other neighbouring markets.

The principal markets are Egypt, other parts of the former Turkish Empire, and neighbouring eastern Mediterranean countries. Small quantities are exported to England and the Continent, but Palestinian wines can in no sense compete in these markets with European wines.

Some sacramental wine is exported to the United States and to other countries, that to the United States amounting to 77,529 gallons during the first six months of 1921.

THE RESIN INDUSTRY IN SPAIN.

The resin, turpentine, pitch and naval stores industry in Spain is controlled by La Union Resinera Española, which made immense profits during the war, and which at present is one of the most powerful trusts in Spain. The Union Resinera Española has recently combined with a German firm for the purpose of enlarging its activities, the new company being called the Industrial Resinera Ruth. The new company will engage in the manufacture of products derived from the distillation and refining of resin, and fish and olive oils. It will make varnishes, enamels, prepared driers, paints, linoleum, glue, aniline and other chemicals, including synthetic camphor.

According to a report by the United States Commercial Attaché at Madrid, the company secures the output of practically all State and privately-owned forests in Spain. A technical forest patrol service is maintained to prevent waste of material, destruction of trees, forest fires, and other similar losses. Trees are kept under careful inspection and the resinous products are secured by a systematic process calculated to keep the forest in the very best possible condition and at the same time secure a maximum output in resinous products.

The production of resinous products in Spain during the years 1915-1919 was as follows:—

Yrs.	Turpentine.	Resin.	Miscellaneous.	Total.
	Kilos.	*Kilos.*	*Kilos.*	*Kilos.*
1915	4,331,429	15,054,593	25,857	19,411,879
1916	4,868,871	16,239,545	48,419	21,156,835
1917	4,599,066	14,364,773	60,829	19,024,668
1918	4,101,384	13,918,298	48,262	18,067,944
1919	3,647,656	11,397,619	96,129	15,141,404

The chief resin-producing centre of Spain is Old Castile. Starting at Villalba, about 30 kilometres north of Madrid, this area is included within a line drawn westward to Segovia, northward to Valladolid, south-eastward to Guadalajara, and west again. There are some scattered sources of production in other parts of Spain, but generally the pine-producing district is in the Guadarrama Mountains transecting Old Castile from Madrid to Valladolid. There is also a resinous district around Leon, and scattered areas occur in the vicinity of Vitoria and north-east of Burgos.

The Province of Segovia may be said to be the most important resin-producing section in Spain. The Canary Islands rank second; the Province of Burgos third; and Valladolid and Salamanca follow in the order of importance.

THE SARAPE INDUSTRY OF MEXICO.

A peculiar and unique industry of the Aguascalientes district is the manufacture of sarapes, or fancy Indian blankets. Founded in a small way about 50 years ago, it has become, writes

the United States Consul at Aguascalientes, the chief manufacturing industry of the district. Establishments for the production of these blankets are found in the cities of Aguascalientes and Zacatecas, the former, however, producing about 83 per cent. of the total output. One factory alone in Aguascalientes turns out one-third of the district's production.

One-third of these sarapes is exported to the United States, the remainder being absorbed by the local trade. These blankets, with their peculiar design and striking colours, would be exported in much larger numbers if the buying public should become familiar with their value and beauty as home decorations and rugs. The sarapes are made in three sizes, 200 by 100 centimetres, 120 by 60 centimetres, 50 by 50 centimetres (centimetre =0.3937 inch), and vary in price according to size and proportion of wool in fabric. The local factories secure their special yarn from the cotton mills in Mexico City.

GENERAL NOTE.

Coffee Industry in Sumatra.—The coffee industry of the East Coast of Sumatra began as a catch crop, the plants being set out between the rows of young rubber trees on estates in the higher altitudes back from the coast. The first picking could be made in about four years, and the coffee bushes would reach their maximum bearing capacity by the time the rubber trees required the entire area for their own growth. The productive area increased from 9,985 acres in 1917 to 15,000 acres in 1921. The yield, however, decreased from 4,028,000 kilos (kilo =2.2 pounds) in 1917 to 1,389,000 kilos in 1921. According to a report by the United States Consul at Medan, the diminution in the yield is attributed to two causes—first, the supplanting of the coffee bushes for rubber trees during the high prices paid for rubber a few years ago, and, second, the serious havoc caused by the coffee borer pest. Since the decline in rubber prices there has been a tendency to replant coffee bushes as an independent crop, but the effect of this movement will not be seen for several years. The total exports of coffee from Sumatra in 1920 and 1921 were 1,872,000 kilos and 1,080,000 kilos respectively. The major portion of this amount went to the Netherlands East Indies, Holland, and Singapore.

MEETINGS OF THE SOCIETY.

Ordinary Meetings.

Wednesday evenings, at 8 p.m.:—

February 7.—Charles R. Darling, F.Inst.P., A.R.C.Sc.I., "Electrical Resistance Furnaces and their Uses." Sir Robert A. Hadfield, Bt., D.Sc., F.R.S., will preside.

February 14.—W. J. Rees, Lecturer on Refractories in the University of Sheffield, "The Durability of Refractories." H. J. C. Johnston, President of the Institute of Clay Workers, will preside.

February 21.—C. Ainsworth Mitchell, M.A., F.I.C., "Handwriting and its value as Evidence." Sir Richard D. Muir will preside.

February 28.—Professor W. E. S. Turner, D.Sc., Head of Department of Glass Technology, The University, Sheffield, "Heat Resisting Glasses." The Hon. Sir Charles A. Parsons, K.C.B., LL.D., D.Sc., F.R.S., will preside.

March 7.—Edward Percy Stebbing, M.A., F.L.S., Professor of Forestry, University of Edinburgh, "The Forests of Russia." The Right Hon. Lord Clinton, Forestry Commissioner, will preside.

March 14.—Sir William Warrender Mackenzie, K.B.E., K.C., President of the Industrial Court, "Industrial Arbitration." Lord Askwith, K.C.B., K.C., D.C.L., Chairman of the Council, will preside.

Indian Section.

Friday afternoons at 4.30 o'clock.

February 16.—J. T. Marten, I.C.S., M.A., Imperial Census Commissioner in India, "The Indian Census of 1921." Sir Edward A. Gait, K.C.S.I., C.I.E., Member of the India Council, will preside.

June 15.—Sir John H. Marshall, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture).

Dominions and Colonies Section.

Tuesday afternoon at 4.30 o'clock.

March 6.—Major E. A. Belcher, C.B.E., Assistant General Manager, British Empire Exhibition, "The Dominion and Colonial Sections of the British Empire Exhibition, 1924." The Rt. Hon. L. S. Amery, M.P., will preside.

Dominions and Colonies and Indian Sections. (Joint Meetings).

Tuesday or Friday afternoons at 4.30 o'clock.

March 16.—Lieut.-Col. Sir Leonard Rogers, C.I.E., F.R.S., F.R.C.P., F.R.C.S.,

Physician and Lecturer, London School of Tropical Medicine, "Recent Advances towards the Solution of the Leprosy Problem."

APRIL 20.—SIR RICHARD A. S. REDMAYNE, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S., "The Base Metal Resources of the British Empire."

MAY 1.—L. GUY RADCLIFFE, M.Sc. (Tech.), F.I.C., "The Essential Oils of the British Empire."

Dates to be hereafter announced:

WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Recent Developments in Surface Combustion."

MAURICE DRAKE, "The Development of Mediæval Technique in Stained Glass Windows."

EDWARD PARNELL, "The Resources and Trade of Sarawak."

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

HENRY P. STEVENS, M.A., Ph.D., F.I.C., "The Vulcanisation of Rubber." Three Lectures. February 5, 12, 19.

SYLLABUS.

LECTURE I. February 5th.—An outline of the changes rubber undergoes when vulcanised. Pre-treatment of the raw material. Vulcanisation process. Physical and chemical properties of vulcanised rubber.

LECTURE II. February 12th.—Methods of vulcanisation. Heat treatment. Vulcanising agents. Cold cures. Accelerators. Vulcanisation of rubber sols and gels.

LECTURE III. February 19th. — Measurement of vulcanising effort. Load-stretch curves. Mineral compounding ingredients. Theories of vulcanisation.

J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards, "Length Measurement." Three Lectures. March 5, 12, 19.

E. KILBURN SCOTT, Assoc.M.Inst.C.E., M.I.E.E. "The Fixation of Nitrogen." Three Lectures. April 9, 16, 23.

HOWARD LECTURES.

Monday evenings at 8 o'clock.

STANLEY S. COOK, "Recent Improvement in Steam Turbines." Three Lectures. April 30, May 7, 14.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, FEBRUARY 5 ... Chemical Industry, Society of, at the Engineer's Club, 39, Coventry-street, W., 8 p.m. (1), Dr. E. Fyleman, "Explosions in Liquid Air Rectification Plants."
(2), Messrs. G. T. Bray and F. Major, "The Estimation of Fat in Casein."

Transport, Institute of, at the Institution of Electrical Engineers, Savoy Street, Victoria Embankment, W.C., 5.30 p.m. Mr. H. W. Gresley, "Wagon Stock on British Railways."

British Architects, Royal Institute of, 9, Conduit Street, W., 8.30 p.m. President's Address to Students and Presentation of Prizes.

Engineers, Cleveland Institution of, Technical Institute, Middlesborough, 6.30 p.m.

University of London, at University College, Gower Street, W.C., 5 p.m., Sir John Russell, "The Micro-Organic Population of the Soil." (Lecture I.); At King's College, Strand, W.C., 5.30 p.m., Rev. C. F. Rogers, "Ecclesiastical Music." (Lecture I.); 5.30, Professor R. Dyboski, "Poland." (Lecture III.); 5.30, Mr. N. B. Jopson, "The Original Home of the Slavs."

Royal Institution, Albemarle Street, W., 5 p.m. General Meeting.

Electrical Engineer's, Institution of, Savoy Place, Victoria Embankment, W.C., 7 p.m. Discussion on "The Supply of Steady D.C. for Telephonic and other Purposes."

Textile Institute, St. Mary's Parsonage, Manchester, 7 p.m. Mr. F. Nasmith, "Artificial Silk and its Application in the Textile Industry."
(London Section), 33, Gresham Street, E.C., 5.30 p.m. Mr. W. Harrison, "Textile Raw Materials."

Engineers, Society of, at the Geological Society, Burlington House, Piccadilly, W., 5.30 p.m. Mr. A. Collis-Brown, "Practical Notes on Inspection."

TUESDAY, FEBRUARY 6 ... Civil Engineers, Institution of, Great George Street, S.W., 6 p.m. Mr. D. H. Remfry, "Wind-Pressures and Stresses caused by the Wind on Bridges."

Metals, Institute of (Local Section), Chamber of Commerce, Birmingham, 7 p.m. Discussion on X-Rays and Crystal Structure.

Oriental Studies, School of, London Institution, Finsbury Circus, E.C., 5 p.m. Mr. N. K. Sidhanta, "The Woman of the Heroic Age in India."

Royal Institution, Albemarle Street, W., 3 p.m. Mr. R. D. Oldham, "The Character and Cause of Earthquakes." (Lecture II.)

Alpine Club, 23, Savile Row, W., 8.30 p.m.

University of London, University College, Gower-street, W.C., 5.30 p.m. Mr. J. H. Helweg, "Contemporary Danish Literature." (Lecture I.) 5.30, Mr. N. H. Baynes, "The Roman Empire in the IVth Century." (Lecture I), at King's College, Strand, W.C.; 5.30 p.m., Miss H. D. Oakley, "The Enigma of Socrates." (Lecture III.); 5.30, Sir Bernard Pares, "Contemporary Russia from 1861." (Lecture III.)

Zoological Society, Regent's Park, N.W., 5.30 p.m. (1), The Secretary, Report on the Additions made to the Society's Menagerie during the months of November and December, 1922. (2), Mr. E. G. Boulenger, Account of Experiments on Amphibians and Insects at Vienna. (3), Mr. C. A. Dighton, "Coat colour in Greyhounds." (4), Mr. Mr. E. L. Gill, "The Permian Fishes of the Genus Acentrophorus." (5), Dr. C. F. Sonntag, "On the Vagus and Sympathetic Nerves of the Terrestrial Carnivora." (6), Mr. E. P. Allis, Jnr.,

"The Postorbital Articulation of the Palato-quadrate with the Neurocranium in the Cœlacanthidæ." (7), Dr. G. S. Giglioli, "On the Linguatulid Arachnid, Raillietiella furcocerca (Diesing, 1835), Sambon, 1922." (8), Rita Markbreiter, "Some Microfilaria found in the Blood of Birds dying in the Zoological Gardens, 1920-1922."

Photographic Society, 35, Russell Square, W.C., 7 p.m. Mr. J. D. Johnston, "The Lantern Slide as a means of Pictorial Presentation and some Technical Considerations."

WEDNESDAY, FEBRUARY 7 .. Industrial League and Council, Caxton Hall, Westminster, S.W., 7.30 p.m. Mr. F. O. Roberts, "Some Obligations of Industry to Labour."

Archaeological Institute, at the Society of Antiquaries, Burlington House, Piccadilly, W., 5 p.m. Mr. F. M. Drake, "The Making of Stained Glass Windows."

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C., 6 p.m. (Wireless Section). Mr. J. Hollingworth, "The Measurement of the Electric Intensity of received Radio Signals."

Sanitary Engineers, Institution of, Caxton Hall, Westminster, S.W., 8 p.m. Mr. P. Griffith, "National Water Resources and their Allocation."

Public Health, Royal Institute of, 37, Russell Square, W.C., 4 p.m. Dr. J. Watt, "Principles and Practice of Sanatorium Treatment."

Geological Society, Burlington House, Piccadilly, W., 5.30 p.m.

United Service Institution, Whitehall, S.W., 3 p.m. Major R. Evans, "The Strategy of the Campaign in Mesopotamia- 1914-1918."

Public Analysts, Society of, at the Chemical Society, Burlington House, Piccadilly, W., 8 p.m., Annual Meeting: (2), Mr. O. Jones, "Notes on the Examination of Preserved Meats, Etc." 3, Mr. E. Griffiths-Jones, "Titanium in Nile Silt."

University of London, University College, Gower Street, W.C., 3 p.m. Dr. T. M. Legge, "Industrial Hygiene." (Lecture I.), 4 p.m. Mr. H. C. Thornton, "The Micro-organic Population of the Soil." (Lecture II.); 5.30, Mr. I. C. Grøndahl, "The Work of Wergeland." (Lecture I.); 5.30, Prof. P. Geyl, "Charles I. and Charles II., and the Princes of Orange." (Lecture I.) at King's College, Strand, W.C., 5.30 p.m. Dr. J. S. Haldane, "The Fundamental Conceptions of Biology."

THURSDAY, FEBRUARY 8 .. Royal Society, Burlington House, Piccadilly, W., 4 p.m.

Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.

Historical Society, 22, Russell Square, W.C., 5 p.m. Anniversary Meeting, Address by the President, the Hon. J. W. Fortescue.

British Decorators, Institute of, Painter's Hall, Little Trinity Lane, E.C., 7.30 p.m. Professor R. A. Bell, "Fresco Painting."

Optical Society,, Imperial College of Science, South Kensington, S.W., 7.30 p.m. Annual General Meeting, Presidential Address.

Central Asian Society, at the Royal United Service Institution, Whitehall, S.W., 5 p.m. Major-General J. A. Douglas, "The Operations on the Bushire-Shiraz Road, 1918-19."

Chadwick Public Lecture, at the Royal Institute of British Architects, 9, Conduit Street, W., 8 p.m. Mr. G. T. Forrest, "London's Unhealthy Areas."

Camera Club, 17, John Street, Adelphi, W.C., 8.15 p.m. Mr. C. H. L. Emanuel, "Notes of a Collector of Prints and Drawings."

London County Council, at the Geffrye Museum, Kingsland Road, E., 7 p.m. Mr. J. Dunkin, "Wood Panelling of Various Periods."

Dyers and Colourists, Society of (Bradford Junior Section), Technical College, Bradford, 7 p.m. Mr. W. Waddington, "Stains on Textiles."

University of London, University College, Gower Street, W.C., 5.30 p.m. Professor A. Cippico, "Atticità Nella Lirica Foscoliana." 5.30 p.m.; Mr. I. Björkhagen, "Swedish Literature in the XVIII. Century." (Lecture II.) 5.15 p.m., Mr. J. E. G. de Montmorency, "French Influence on English Customary Law."

At King's College, Strand, W.C., 5.30 p.m. Professor W. Barthold, "The Nomads of Central Asia." (Lecture IV.) 5.30 p.m., Dr. O. Vocadlo, "Modern Czech Novelists." (Lecture III.)

At the London Hospital Medical College, Turner Street, E., 4.30 p.m. Mr. W. A. M. Smart, "The Mathematical Basis of Physiological Problems." (Lecture IV.)

Royal Institution, Albemarle Street, W., 3 p.m. Professor I. M. Heilbron, "The Photosynthesis of Plant Products." (Lecture II.)

Mechanical Engineers, Institution of (Midland Branch), The University, Birmingham, 7.30 p.m. Mr. C. Poole, "Escalators."

Metals, Institute of, at the Institute of Marine Engineers, 85, Minories, E.C., 8 p.m. Miss M. L. V. Gayler, "The Investigation of the Constitution of Alloys."

FRIDAY, FEBRUARY 9 .. London Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5 p.m. Mr. M. Macartney, "Wren's Work in London."

Royal Institution, Albemarle Street, W., 9 p.m. Sir John Russell, "Rothamsted and Agricultural Science."

Anglo-Batavian Society, at the Birbeck College, Bream's Buildings, Fetter Lane, E.C., 6 p.m. Mr. J. A. J. de Villiers, "The Dutch in South Africa."

Physical Society, at the Imperial College of Science, South Kensington, S.W., 5 p.m.

Japan Society, 20, Hanover Square, W., 5 p.m. Mr. R. W. Bewick, "The Problems of the Far East."

Timber Trade Lectures, London Chamber of Commerce, Oxford Court, Cannon Street, E.C., 6.30 p.m. Mr. H. J. Townsend, "Plywood."

Dyers and Colourists, Society of (Scottish Section), Glasgow, 7 p.m. Mr. E. W. Fearnside, "British Progress in Fast Wool Colours."

Metals, Institute of (Sheffield Section), (Conjoint Meeting with the Faraday Society), at the University, Sheffield, 7.30 p.m. Symposium on "Stainless and Non-Corrodible Alloys."

Malacological Society, at the Linnean Society, Burlington House, Piccadilly, W.

University of London, University College, Gower Street, W.C., 8 p.m. Miss E. J. Davis, "The Evolution of London." (Lecture I.) At King's College, Strand, W.C., 5.30 p.m. Mr. W. C. Bolland "Chief Justice Sir William Beresford," 5.30. Dr. R. W. Seton-Watson, "Serbia and the Jugo-Slav Movement." (Lecture IV.)

SATURDAY, FEBRUARY 10 .. Royal Institution, Albemarle Street, W. 3 p.m. Mr. J. C. Squire, "Subject in Poetry." (Lecture II.)

Dyers and Colourists, Society of (Local Section), George Hotel, Huddersfield, 7.15 p.m. Paper by Mr. J. H. Garner.

Journal of the Royal Society of Arts.

No. 3.664 VOL. LXXI.

FRIDAY, FEBRUARY 9, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

FUND FOR PURCHASING AND RENOVATING THE SOCIETY'S HOUSE.

SEVENTH LIST.*

	£	s.	d.
Amount previously acknowledged	42,830	18	4
Messrs. Bryant & May, Ltd...	100	0	0
Frank Bailey, Esq.	10	10	0
Professor J. Uri Lloyd, Ph.D., LL.D.	6	17	0
Thomas L. Gray, Esq. ..	5	0	0
Fred E. V. Beanes, Esq. ..	2	2	0
Cecil Brown, Esq., M.Inst.C.E.	2	2	0
Frank John Pickthall, Esq...	2	2	0
Anonymous	1	1	0
Vasudee Bhandarkar, Esq. ..	1	1	0
Noel A. Brown, Esq... ..	1	1	0
Edwin John Chapman, Esq...	1	1	0
Arthur R. Griggs, Esq. ..	1	1	0
J. J. Elmer, Esq.	1	0	0
Pandit Sri Krishen Gurtu, M.A., M.Inst.C.E.	1	0	0
Mrs. F. M. Clegg		10	0
Robert W. Maxwell, Esq. ..		7	0
	42,967	13	4

The above list includes all subscriptions received up to January 31st. Further lists will be published in the *Journal* from time to time.

Fellows of the Society are reminded that the amount aimed at by the Council is £50,000, which will cover the cost of renovating and decorating the House.

* The six former lists were published in the *Journals* of December 2nd, 1921, January 13th, February 24th, May 5th, July 14th, and November 17th, 1922.

NOTICES.

NEXT WEEK.

MONDAY, FEBRUARY 12th, at 8 p.m. (Cantor Lecture.) HENRY P. STEVENS, M.A., Ph.D., F.I.C., "The Vulcanisation of Rubber." (Lecture II.)

WEDNESDAY, FEBRUARY 14th, at 8 p.m. (Ordinary Meeting.) W. J. REES, Lecturer on Refractories in the University of Sheffield, "The Durability of Refractories." H. J. C. JOHNSTON, President of the Institute of Clay Workers, will preside.

FRIDAY, FEBRUARY 16th, at 4.30 p.m. (Indian Section). J. T. MARTEN, I.C.S., M.A., Imperial Census Commissioner in India, "The Indian Census of 1921." SIR EDWARD A. GAIT, K.C.S.I., C.I.E., Member of the Council of India, will preside.

Further particulars of the Society's meetings will be found at the end of this number.

NINTH ORDINARY MEETING.

WEDNESDAY, JANUARY 31st, 1923; SIR HUMPHRY DAVY ROLLESTON, K.C.B., M.D., D.C.L., President of the Royal College of Physicians, in the Chair.

The following Candidates were proposed for election as Fellows of the Society :—

Angell, Colonel Frederick John, C.B.E., Bedford.
Angus, J. A., Rangoon, Burma.
Armstrong, Thomas Francis, Kathiawar, India.
Crosby, Lieut.-Colonel Walter Wilson, D.Sc., M.Am.Soc.C.E., Grand Canyon, Arizona, U.S.A.
Kinsman, Arthur Daniel, Ipswich, Mass., U.S.A.
Leaf, E. L., London.
Lloyd-Dodd, A. E., B.Com.Sc., Lisburn, Ireland.
McLaughlin, Robert Samuel, Ontario, Canada.
Singh, S. Inder, Cawnpore, India.
Townsend, Sydney Robert Maurice, London.

The following candidates were balloted for and duly elected Fellows of the Society :

Acton, Murray Adams, London.
Ayer, S. K., B.A., South India.

Beaumont, R. H., Wollaton, nr. Nottingham.
Carpenter, Charles L., Porto Rico, West Indies.
Carrier, Willis H., Newark, New Jersey, U.S.A.
Fremantle, Alan Frederick, London.
Gillespie, John, F.S.A. (Scot.), Pollokshields, Glasgow.
Hardless, Charles, Chunar, India.
Hardless, Charles, jun., B.A., Chunar, India.
Hardless, Harold Richard, Chunar, India.
Harkness, Gustavus, Spring City, Pa., U.S.A.
Herring, John P., Bloomsburg, Pa., U.S.A.
Jillson, Willard Rouse, B.S., M.S., Sc.D., Frankfort, Kentucky, U.S.A.
Kar, Upendranath, M.A., B.E., Calcutta, India.
Kodaisia, A. P., Chhatarpur State, India.
Lim Kim Seng, Singapore, Straits Settlements.
Mallik, N. D., Karachi, India.
Nosworthy, Frederick, London.
Pudumjee, Khan Bahadur B.D., Bombay, India.
Ratcliffe, Ellis, Keighley.
Rice, Prof. Ambrose Clark, B.Sc., B.Ph., Grand Island, Nebraska, U.S.A.
Russell, David, LL.D., Markinch, Fife.
Seddon, S. H., M.I.M.E., Calcutta, India.
Singh, Raja Bahadur Naba Kishore Chandra, Hindol, Orissa, India.
Singh, S. Govinda Prasad, Mirzapur, U.P., India.
Spreat, Captain S. H., London.
Stuart, Nigel, New York City, U.S.A.
Tannan, Mohan Lal, B.Com., Bombay, India.
Towne, George Lewis, A.B., Lincoln, Nebraska, U.S.A.
Volck, William Hunter, Watsonville, California, U.S.A.
Wood, Prof. Edwin Ellsworth, M.A., LL.D., Williamsburg, Kentucky, U.S.A.
Zwally, E. L., Pittsburgh, Pa., U.S.A.

The Mann Lecture on "The Relation between Chemical Constitution and Antiseptic Action in the Coal Tar Dyes," was delivered by Mr. Thomas H. Fairbrother, M.Sc., F.I.C., and Dr. Arnold Renshaw, D.P.H.

The lecture and discussion will be published in a subsequent number of the *Journal.*

BINDING COVERS FOR JOURNALS.

For the convenience of Fellows wishing to bind their annual volumes of the *Journal*, cloth covers can be supplied, post free, for 2*s*. each, on application to the Secretary.

LIST OF FELLOWS.

The new edition of the List of Fellows of the Society is now ready, and copies can be obtained on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

BROWN COALS AND LIGNITES.

By William Arthur Bone, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology.

Lecture III.—*Delivered* 11*th December*, 1922.

THEIR THERMAL DECOMPOSITION AND CARBONISATION AT DIFFERENT TEMPERATURES.

Although the problem of carbonising brown coals and lignites presents many features of interest to a fuel technologist, as yet too little experience has been gained from actual large scale practice to warrant any definite conclusions being formed as to the profitableness of the results obtainable thereby. So much depends upon the nature of the raw coal and other local circumstances, that each case must be considered separately on its merits, after careful experimental investigation.

Therefore, instead of speculating about the commercial possibilities of, say, the low temperature carbonisation of these semi-mature coals (for such they are), I propose merely to discuss how recent laboratory-scale experiments have elucidated the general character of their thermal decomposition at different selected temperatures, and the nature of the products obtainable therefrom.

The apparatus employed in the investigation, was one which was designed and tested out some five years ago in the Fuel Laboratories of The Imperial College, at the instance of the Fuel Research Board, and is now in regular use as our standard laboratory assay method for the carbonisation of coal. It permits of the carbonisation of a small charge of coal being studied at any selected temperature in such a manner as to allow of an accurate measurement of the various products (coke, oils, ammonia, liquor and gas) being made. The results as regards the yields of coke, gas and ammonia from a given coal are practically identical with those obtained in large-scale practice, although the yield of oil usually exceeds somewhat that obtained for the same coal on a commercial plant. From the point

of view of our present purpose, the methods give comparative results of great value when the behaviour of a number of different coals is to be investigated.

It may here be pointed out that, inasmuch as brown coal and lignites are all quite devoid of caking properties, and also have high oxygen contents, their thermal decomposition presents features differing from those exhibited by the more mature bituminous coals and, therefore, requires special consideration. Thus, for example, that portion of the coal substance derived from the lignocelluloses of the original vegetable debris has, in the case of brown coals and lignite, undergone far less change, and is, therefore, more pronouncedly cellulosic in character than the corresponding constituents of bituminous coals. In my last lecture it was shown that the first action of heat upon brown coals and lignites is to effect a chemical condensation, at comparatively low temperatures (below 400°C), in their "cellulosic" constituents whereby large quantities of steam and carbon dioxide are expelled therefrom. Indeed, steam and oxides of carbon are prominent among the decomposition products at all temperatures; and a careful study of the oxygen distribution among such products at various temperatures will usually repay amply for the time expended upon it.

After these introductory words I will now draw your kind attention to the following tabulative results, shewing the amounts of various gaseous products (in cubic feet at 0° 760 mm per ton) obtained in a series of trials at different temperatures between 375° and 850°C, with a brown coal (previously well dried) containing about per cent. of oxygen.

I wish you particularly to observe—for such results are typical for brown coal as a class—

(1) That up to a certain temperature limit—in this case 375° C—the only gases to be expelled are steam and oxides of carbon (chiefly CO_2), as the result of an initial "cellulosic condensation" in the coal substance, which probably continues right up to and (perhaps beyond) 700°C.

(2) That there then follows a temperature range—in this case 375° to 500°—in which methane and hydrocarbons CnHm, but *not* hydrogen, appear; from which it is evident that, in addition to the aforesaid "cellulosic condensation," the coal complex itself begins to decompose. Such decomposition is signalised by the elimination of condensable 6-carbon ring (hydrobenzoid) compounds *plus* saturated hydrocarbons (methane and homologues), the latter being probably produced by the elimination of "side chains" from the former. It is during this stage that oils first appear among the condensable products.

(3) That at a still higher temperature range—in this case 500-700°—hydrogen appears for the first time in the products, a circumstance indicative of the gradual progressive conversion of 6-carbon saturated ring compounds into the corresponding benzenoid derivatives. The oil yield usually reaches a maximum at about 750° C.

(4) That in the highest range—700° to 850°—covered by the experiments, the evolution of gaseous products still increases. In so far as such increase is in the amounts of oxides of carbon and steam, it may be ascribed in large part to the continuance of the aforesaid "cellulosic" condensation or decomposition; but any increase in the

TABLE I.

GASES OBTAINED BY THE THERMAL DECOMPOSITION OF A TYPICAL DRY BROWN COAL CONTAINING 30 PER CENT OXYGEN.

Temperature.		375°	500°	700°	850°
Cub. Ft. 0° C at 760 mm. per ton.	H_2S ...	20	70	110	130
	CO_2 ...	1,180	2,825	3,010	3,841
	CO. ...	55	565	1,360	2,280
	CnHm ...	15	40	175	150
	CH_4 ...	nil	600	1,570	1,930
	H_2 ...	nil	nil	755	2,920
Total cubic feet ...	...	1,270	4,100	6,980	11,250
lbs. Oxygen per ton evolved as	$CO_2 + CO$	108	279	331	445
	H_2O ...	109	153	181	211
	Total ...	217	432	512	656

amounts of inflammable gases is almost always at the expense of the oil yield.

(5) That in this case decomposition was practically completed at 850°C., as is indicated by the fact that practically the whole of the oxygen originally present in the coal had now been expelled in the form of steam and oxides of carbon.

The carbonaceous residues produced from this coal at all temperatures up to the highest were non-coherent, but could easily be briquetted with a suitable proportion of pitch or binder. All were free burning and highly combustible; and those obtained at temperatures of 500° and upwards burnt practically smokelessly. A consideration of the very large proportion of carbon dioxide always present in the gaseous products at any temperature will shew how unattractive brown coals are from the ordinary "gas-making" point of view. Indeed, any idea of making a good towns-gas from them is rather remote, the main objective in carbonising them being to upgrade them for domestic and industrial use, and incidentally also to recover oils and possibly also ammonia rather than to produce gas from them.

Having thus described some of the more salient features of the thermal decomposition of a typical brown coal containing about 30 per cent. of oxygen, I will now proceed to indicate how the relative weight yields of residue, oils, liquor and gas may be expected to vary with the temperature.

For this purpose I have selected the following results (Table II.) of trials with (*a*) Morwell brown coal, (*b*) a Saskatchewan lignite, and (*c*) a more mature black lignite of Burmese origin.

For purposes of comparison, the results of low temperature carbonisation trial (at 600°C) upon some representative British bituminous coal are given below :—

Yields for Bituminous Coals at 600°C.

	Per cent. on dry coal.
Residue	73 to 77
Liquor	3.5 to 7
Oils	6 to 8
Gas	10 to 15*

*3,000 to 4,000 cub. ft. per ton.

It would therefore appear that, broadly speaking, brown coals and lignites will, on being carbonised at low temperatures (500 to 700°C), be expected to yield considerably more liquor, but less oils, than do bituminous coals. Moreover, though the carbonaceous residues obtained from them are always free burning highly combustible smokeless fuels, they are (unlike those from caking bituminous coals) non-coherent, and must be burnt either as pulverised fuel or after being briquetted. Consequently, their low temperature carbonisation on a commercial scale should not be undertaken lightly, and without the most careful consideration of local circumstances, and of the chemical character of the oils produced. In some cases the latter may be of considerable value. Indeed, each case must be considered separately on its own merits after careful experimental trials and a thorough chemical investigation of the oils obtained.

[At this point typical specimens of the various fractionated products obtained by the low temperature carbonisation of a black lignite were exhibited and described. These included (1) smokeless briquetted solid fuel (steam coal), (2) motor spirit, (3) kerosene oils, (4) fuel oils, (5) pitch, and (6) wax-like substances.]

TABLE II.

Shewing Percentage Weight-yields of Products at different Temperatures from Typical Coals.

	Morwell Brown Coal.			Saskatchewan Lignite.			Burmese Lignite.		
Temp. C°	500°	700°	850°	500°	700°	850°	500°	700°	850°
Residue ...	67.6	53.3	50.9	69.7	62.0	60.2	70.7	60.0	59.0
Liquor ...	7.7	9.1	10.6	8.7	10.1	9.5	10.3	11.3	9.9
Oils & Tar	3.5	8.3	3.3	2.5	2.9	1.8	3.0	3.8	2.2
Gas ...	19.4	26.6	35.6	20.3	25.2	29.3	15.5	24 0	29.1

It is premature to lay down any general rule as to the selection of the best carbonising temperatures from the point of view of profitable working because so much depends on the nature of the coal itself and local market conditions. In some cases the determining factor might be the production of the most suitable carbonaceous residue

for a specific purpose, such as either the manufacture of a smokeless briquetted fuel or maybe for use as a pulverised fuel in furnaces or boilers. In the latter case the carbonisation should not be pushed beyond the point that will give a residue containing between 10 and 15 per cent. of volatiles. In other cases, the obtaining of a maximum yield of oils would be the deciding factor. It is questionable whether in most cases the production of gas in quantities beyond what may be needed to maintain the carbonising temperature in the setting will be a factor of prime importance.

Complete Gasification in Gas Producers.

As already stated in my paper of February last, there is no particular difficulty about completely gasifying lignites by means of a mixed steam-air blast in producers, and, provided the nitrogen content justifies it, ammonia recovery may be profitably undertaken. By the courtesy of the Power Gas Corporation I am able to quote the following results of measured trials carried out under ammonia recovery conditions upon French and Italian lignites in a Mond By-product Peat Gas Producer Plant at Orontano; these have been amply confirmed by similar trials upon lignites of various origins conducted under my own supervision.

	French Lignite (from La Savoie).	Italian Lignite (Ribollo).
	per cent.	per cent.
Moisture in Coal charged ..	.. 40.5	8.5
The Dry Fuel contained:		
Fixed Carbon ..	.. 33.9	—
Volatiles ..	.. 50.1	—
Ash	.. 17.7	16.2
Nitrogen	.. 1.8	1.9
Yield of Gas:		
Cub. Ft. at 15° C. per ton Dry Fuel	78,300	71,700
	per cent.	per cent.
Composition of the Gas:		
CO_2	.. 20.8	16.3
CO	.. 10.6	11.5
H_2	.. 25.6	26.3
CH_4	.. 5.4	4.8
N_2	.. 37.6	41.1
	100.0	100.0
Yield of Ammonium Sulphate in lbs. per ton of Dry Coal	.. 92.5	130

Steam Raising Problems.

So far as can be seen at present, the production of cheap electric power from brown coals and lignites in steam-turbine stations is likely to be largely developed in localities where such fuels abound and can be cheaply won, and where large demands for industrial power either exist or can be counted upon. Already the Victorian Government has boldly taken the plunge at Morwell, where, as stated in my first lecture, a huge modern power station is now being erected. Should this fulfil the expectations of its promoters, other favoured localities will, doubtless, in time follow suit. It is, therefore, appropriate that I should conclude these lectures by a further reference to the steam raising problem.

In power-station work, perhaps the two most important considerations in regard to the boiler installation are those of thermal efficiency and a large steam output per unit; and it is just in regard to these that such low grade fuels as brown coals and lignites present most difficulties, and especially so if they are used in anything like the raw state. For economical working, it is necessary to ensure a large output of steam per boiler, together with a reasonably good thermal efficiency, because of the high capital outlay involved in the installation of modern mechanically-stoked water tube boilers with superheater or feed water heating devices. Until lately, however, engineers seem to have been content with the comparatively poor results obtainable with the raw fuels, without giving sufficient thought to the possibilities of drying and up-grading them.

As an example of the state of things up to a few years ago, I recently came across an official report of some boiler trials with Saskatchewan and Alberta lignites, which gave thermal efficiencies varying between 52.5 and 63.9 per cent., and from which the remarkable conclusion was drawn that the moisture content of the coals up to 30 per cent. did not materially affect the boiler efficiency.

In Table III., which is taken from the report of the Committee appointed in 1917 to advise the Victorian Government regarding the prospective use of brown coal for power and other purposes, are shown the results of official steam trials upon Morwell brown coal, containing (as fired) from 44 to 46 per cent. of moisture, carried out in that year at the Melbourne City Council's Power House, with a Babcock and Wilcox water

tube boiler operating at its rated steam output.

TABLE III.

BOILER TESTS WITH MORWELL BROWN COAL.

Type of Boiler. Babcock and Wilcox Water Tube, Heating Surface 3,654 sq. ft. Normal rated capacity 12,600 lbs. steam per hour.

Type of Furnace. Semi-producer type. Grate area=49 sq. ft.

No. of Trial.	1	2	3	4
Date	4/8/17	15/8/17	17/8/17	20/8/17
Duration in Hours	6.5	6.0	6.5	6.0
Steam pressure lbs. per sq. inch	163	163	164	160
Temperature C°.				
Gas leaving boiler	266°	266°	300°	388°
Feed Water	97°	97°	96°	100°
Steam	273°	271°	264°	260°
Pre-heated air to furnace	89°	87°	90°	83°
Fuel.				
Total lbs. coal consumed	28,672	20,832	30,688	25,760
Lbs. coal consumed per hour	4,412	3,472	4,721	4,293
Lbs. coal per sq. ft. of grate area per hour ...	90	70.9	96.4	87.6
% moisture in coal as fired	44.0	45.3	46.0	45.4
Water evaporated.				
Total lbs. during test	101,000	72,300	104,500	97,700
Average lbs. per hour	15,540	12,050	16,080	15,450
Economic Results.				
Evaporation in lbs. water from and at 100° C. per lb. coal as fired	4.01	3.95	3.86	4.04
Calorific value of coal as fired b.th.u. per lb. ...	6,756	6,857	6,136	6,233
Efficiency of Boiler and Air Heater with Coal as fired	57.3%	55.6%	60.7%	62.6%

Considering the fact that the coal as fired contained so much moisture, and that the boiler furnace was probably not specially designed for such a low grade fuel, the above results may be regarded as being reasonably good from the point of thermal efficiency, although the evaporation per square foot of heating surface was undoubtedly low. I should expect much better results to be obtainable with a dried-coal and a furnace specially designed to burn it.

With regard to the question of furnace design, in the year 1919 Henry Kreisinger and his collaborators of the U.S. Bureau of Mines conducted an experimental investigation with a view to determining the best conditions under which a North Dakota lignite or its carbonised residue should be burnt in boiler and other furnaces. The raw fuel used by them contained about 35 per cent. of water, and when charged in a lump condition into the hot furnace it rapidly developed cracks and then crumbled into small pieces. They concluded that two conditions are requisite in the furnace for its proper combustion, namely :—

(*a*) provision must be made for rapid ignition ; and

(*b*) the furnace must be capable of supplying enough air with ordinary draught to produce a reasonably high rate of combustion and make a hot fire.

In the opinion of the American investigators, rapid ignition is best effected by the use of a rear arch, fixed nearly parallel with the plane of the grate which will turn all hot gases and flames back over the fuel bed. They claim that in such wise the fresh fuel is heated up to its ignition temperature, mainly through contact with hot gases and flames from the already burning fuel. Two such furnace arrangements suggested in their paper are reproduced in Fig. 9.

As already stated in my second lecture, the burning of brown coals or lignites in anything like a raw state is, from every point of view, to be deprecated. And even such improved furnace construction as was recommended by the American investigators will not overcome the inherent disadvantages of burning an undried fuel in the boiler grate. In my opinion, no large power-station boiler installation for

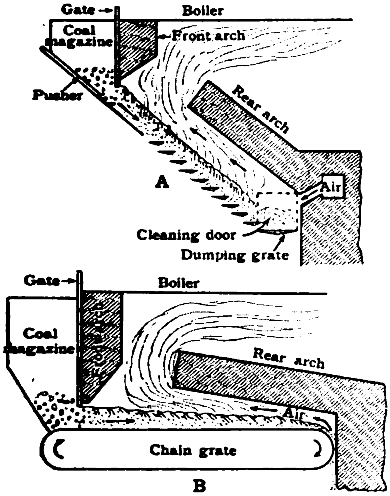


FIG. 9.

brown coals or lignites ought to be without some auxiliary drying and upgrading appliance, the systematic use of which would always be amply repaid in higher thermal efficiency and large steam outputs per unit.

This brings us back again to the question of how the raw coal may best be dried and upgraded in such an auxiliary appliance. Soon after my discovery that brown coals and lignites (and particularly the former) may be upgraded by a simple heat treatment, as described in my preceding lecture, it occurred to me that perhaps the readiest and most economical way of doing so for boiler installation would be to combine the "drying" and "upgrading" in one continuous operation, using for such purpose the sensible heat in the burnt gases passing away from the boiler itself, assuming them to contain more than ten per cent. of carbon dioxide, and to leave the boiler at a temperature of 400°C. or more. In other words, my idea was to substitute for the usual "economisers" behind the boiler in which the feed-water is pre-heated, some simple and relatively much cheaper device in which the incoming raw fuel could be both dried and upgraded at the expense of the sensible heat of the burnt products leaving the boiler.

At this juncture I got into touch with Mr. W. R. Wood, General Manager of the Underfeed Stoker Company, of London, who already had gained considerable experience of burning such low-grade fuels under boilers. He at once saw the advantages of such a proposal, and deemed it quite practicable. At his suggestion the Underfeed Stoker Company undertook to see what could be done to give effect to it in practice. Ultimately they designed and patented an apparatus for the purpose which can be attached to a water-tube boiler. For want of a better name, I will, for the present, call it the "fuel improver" attachment, because it is designed to effect the double purpose of drying and up-grading the ingoing raw fuel at the expense of part of the heat of the outgoing products of its combustion. The following diagram (Fig. 10) shows the general arrangement of a water-tuber boiler with mechanical stoker fitted with one of such attachments as designed by the Underfeed Stoker Co., which has been installed by the Victoria Government Electricity Commissioners in connection with an experimental boiler unit at Morwell; and I understand that it is undergoing systematic trials there under the supervision of Mr. H. R. Harper, their Chief Engineer.

The boiler B is of the Babcock Wilcox type, and is fitted with a self-contained forced-draught travelling grate stoker C; the heating surface of the boiler is 2,436 sq. ft., and the grate area is 85.7 sq. ft. The "fuel improver" attachment D is constructed of a sheet iron casing, made practically air-tight, and is fitted with two parallel series of cast-iron plates, which are sloped at an angle of about 80° with the horizontal, so as to form a chute with open sides, the plates being arranged in the form of louvres.

The raw coal is automatically fed into the top of the chute, and in slowly passing down it encounters a directed flow of the hot products of combustion from the boiler setting, whereby it is first of all dried and afterwards "up-graded" in accordance with the plan already described. In this particular installation it should be observed that the hot gases as they leave the boiler come in contact first of all with the raw incoming fuel; in other words, the relative passages of the fuel and gases through the apparatus are not on the contra-flow principle As originally designed, it was intended that they should be on that principle; but it was afterwards thought better in this first trial unit to depart from it, because there would be less likelihood of the fuel becoming ignited during its passage down the chute if the gases met the raw fuel with its maximum water content at their highest temperature. It is hoped, however, that

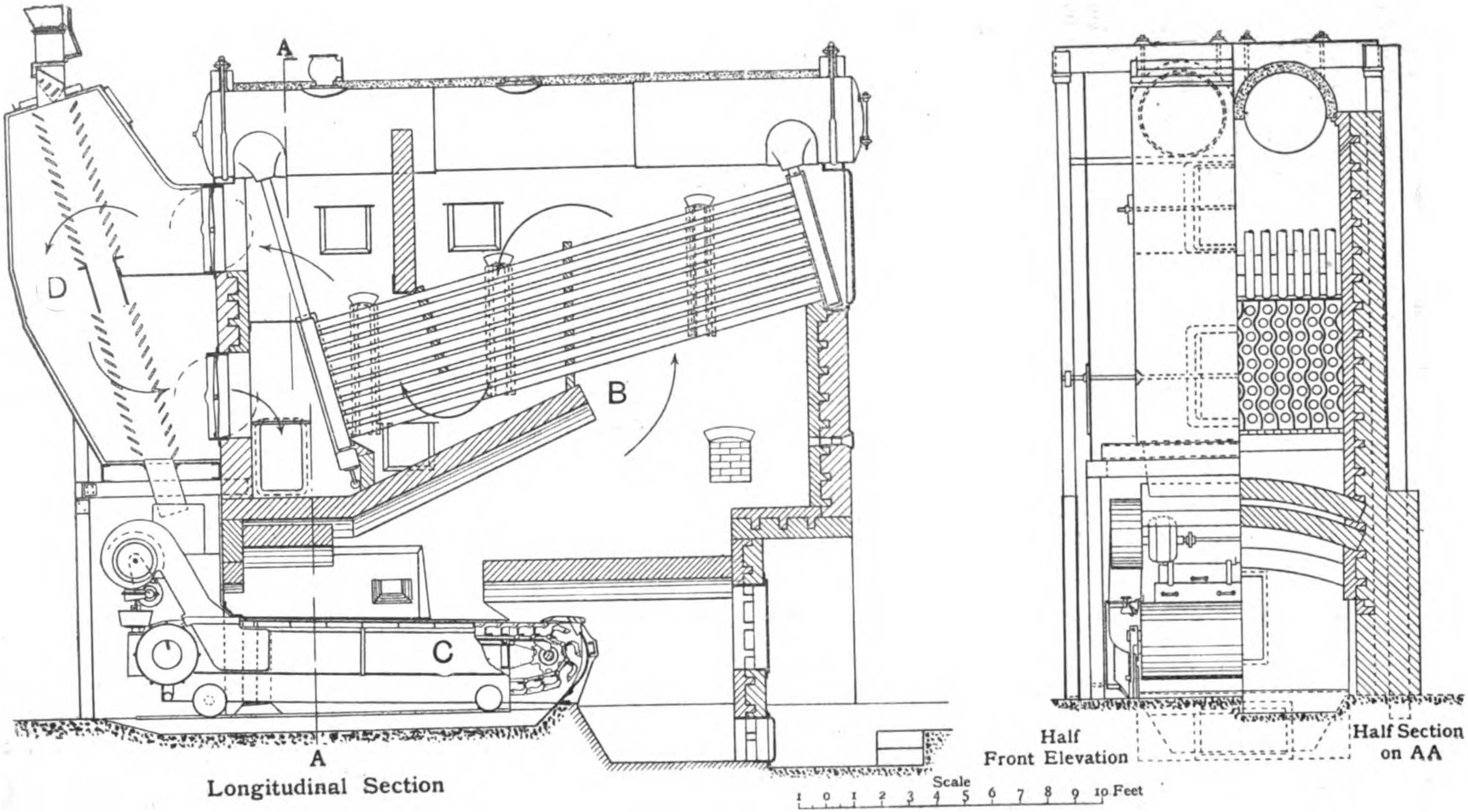


FIG. 10.—General arrangement of Boiler and Mechanical Stoker, with "Fuel Improver" Attachment as installed for trial by the Victoria Government Electricity Commissioners at Morwell, Australia.

the result of these trials will shew this to be an unnecessary precaution, in which case the contra-flow principle will be adopted in future installations. The chute is capable of containing about 2.1 tons of raw fuel which at the present rate of operating takes about 45 minutes in passing through the apparatus.

One of the principal advantages which it is expected will be gained by the use of such a "fuel-improver" in connection with big power-station boiler installations, such as the one contemplated at Morwell, where a low-grade but cheap brown coal must be used, is that drying and "up-grading" the fuel, before it is burnt in the boiler grate, will give a much hotter and more radiant fire than it would otherwise do, with consequent increase in both the steam output per boiler, and the thermal efficiency of the system as a whole. In other words, it is confidently anticipated that, owing to the higher furnace temperature which will certainly be realised when such a fuel-improving arrangement is employed, the rate of heat transmission throughout the boiler will be greatly improved. Indeed, in submitting their scheme for the Morwell contract, the Underfeed Stoker Co. guaranteed that nine boilers fitted with their new "fuel improver" attachment would give the same steam output as twelve boilers fired with the untreated fuel, and with a greater thermal efficiency.

As the trials of the apparatus are not yet completed, it would be premature for me to attempt in this paper to pass any final judgment thereon. But judging from the results which have so far been reported to me, I am able to say that it seems probable that the anticipations of the Underfeed Stoker Company will be amply fulfilled when the final results are known. For it has already been proved that, after passing through the "fuel improver" attachment to the boiler, the fuel burns very freely and can be efficiently consumed at high rates of combustion; also that the treatment of the fuel brings about a marked increase, both in the furnace temperatures and in the rate of heat transmission throughout the boiler.

Thus, for example :—

(1) In a trial carried out on 6th October last, in which the *raw* fuel was burnt *without being passed through the "fuel improver" attachment*, the rate of combustion in the grate was 34.9 lbs. per hour, and the water evaporated 6,550lbs. per hour. The furnace temperature was 928° C. (1,702° Fahr.); and the products of combustion leaving the boiler at 292° C. (557.7° Fahr.) continued CO_2=10.3, CO=1.7, and O_2=7.4 per cent.

(2) In a similar trial, carried out on the following day, *in which the same fuel was passed through the "fuel improver" attachment*, the rate of combustion was 94.05 lbs. per sq. ft. of grate per hour, and the water evaporated was 20,200 lbs. per hour, the furnace temperature was 1,149°C. (2,100° Fahr.); and the products of combustion leaving the boiler at 315° C. (599° Fahr.), but the "fuel improver" attachment at 92°C. (198° Fahr.), contained CO_2=13.5 CO=0.33, and O_2=5.6 per cent.

The foregoing figures are quoted just as they have been reported to me, but it is to be understood that they represent the results of two quite preliminary trials only, and that no finality is here claimed for them. I hope in due course to receive reports of further and more exhaustive trials, until which time I shall prudently reserve any final expression of opinion.

The experiment is, however, a most interesting one, and, if (as we hope) successful, it will open up possibilities of considerable value from the point of view of power-station work. Perhaps on some future occasion I shall have more to say on the subject.

A Plea for Systematic Research.

In concluding these lectures, which necessarily have dealt with the subject in outline only, leaving some aspects of it untouched, may I be allowed to put in a plea for more systematic scientific research into it? Such investigation as has been possible up to now has merely touched the fringe of the subject, leaving the greater part of it unexplored. It is to be hoped that the various Governments interested in the matter throughout our Dominions will realise the importance of building up a strong brown-coal technology within the Empire on the basis of well-directed scientific research. We are at the beginning of the economic utilisation of the potential energy and by-product possibilities of vast natural brown coal resources in both

Australia and Canada. The little which has been done up to the present in the way of scientific research into them is as nothing compared with what might be accomplished, if only the great opportunities which now present themselves are seized and made the most of.

Finally, I desire to express my best thanks to the Hon. John McWhae, the Agent-General for Victoria, the Lignite Utilisation Board of Canada, the Lignite Research Company of London, Mr. W. R. Wood and the Underfeed Stoker Company of London, Messrs. Yeadon, Son and Company, of Leeds, the Power Gas Corporation, and to Mr. W. E. King, A.R.C.S., of the Imperial College, South Kensington, and other friends for their kind help in connection with these lectures and the researches on which they are based.

NOTES ON BOOKS.

Villas of Florence and Tuscany. By Harold Donaldson Eberlein. Philadelphia and London: J. B. Lippincott Company; New York: The Architectural Record Company. £3 3s. net.

Visitors to Tuscany are familiar with many of its magnificent villas which enjoy a world-wide reputation; but in addition to these princely "show-places" there are a large number of comparatively small country houses, unknown to the ordinary tourist, which yet possess a particular charm of their own, and are in their way no less than the great "villas" expressive of the artistic grace so characteristic of Tuscany. Mr. Eberlein has made a careful study of many, if not all of these, and the present volume gives the result of his researches. His method is to a certain extent new. Instead of attempting to give a general impression of his whole subject, he selects twenty-three villas, and deals with each of these with admirable thoroughness. In the case of the Villa Caponi, Arcetri, for instance, he gives no fewer than twenty plates, including plans of the house and gardens, and photographs of the most important characteristics of the building: these, with a page and a half of description, enable the reader to gain a wonderfully complete idea of the whole villa, both inside and out, and of the delightful gardens and iron gates which are such attractive features of the place.

While there is a certain family resemblance amongst the villas described, there is at the same time a great and pleasing variety, so that among the three hundred illustrations one never is troubled with any feeling of monotony. Most of these illustrations are from photographs taken by the author. They are excellent in every way—in choice of subject, in photographic skill and in reproduction. The book is a joy to the lover of Italian architecture, and to most readers it will be a revelation to learn what a wealth of delightful houses is contained in Tuscany.

CASTOR OIL PRODUCTION IN ARGENTINA.

Castor oil is prepared from the seed of the "tartago" or castor-oil plant which has been grown in northern Argentina for many years. While the plant grows as far south as the 40th parallel, its practical cultivation is limited to that part north of the 30th parallel. From 3,000 to 4,000 hectares (1 hectare equals 2.47 acres) are cultivated each year, distributed approximately as follows among the Provinces and Territories: Chaco Territory, about 2,000 hectares; Entre Rios, 1,000 hectares; Corrientes and Tucuman, each less than 500 hectares while there are small quantities produced in Misiones, Formosa, Salta, Santa Fe, and Santiago del Estero.

The variety cultivated in Argentina, writes the United States Trade Commissioner in that country, is designated as "ricino colorado" or red castor bean (*Ricinus sanguineus*). In the Chaco Territory the seed is sown in August, and ripens within four to six months after the planting. Calculations are based on a production of 1 metric ton (1 metric ton equals 2,204.6 lb.) of seed per hectare, but a crop of 2 tons is often produced, and a yield as high as 3 tons per hectare has been recorded in the Chaco. According to an analysis made by the Argentine Department of Agriculture, the castor bean grown near Resistencia, Chaco, yielded 52 per cent. of oil.

There are five important factories in Argentina producing castor oil and several other vegetable-oil factories that manufacture it on occasion. In these factories the oil is extracted both by the cold and the hot process. The product is used both medicinally and industrially. The production of castor oil in Argentina is estimated to be between 1,000,000 and 1,250,000 litres (1 litre equals approximately 1¾ pints), all of which is consumed locally. Up to the present the castor-oil cake has found no application except as fuel since fertilizers are not ordinarily used in the country.

There is an extensive territory in Argentina well adapted to the cultivation of the castor-oil plant, and the farmers of the northern part of Argentina are ready to produce more of the seed if there is a larger market. The oil manufacturers also claim to be able to produce a much greater quantity of castor oil if the market warrants it.

AGRICULTURAL DEVELOPMENT IN THE CAMEROONS.

The current number of the *Bulletin of the Imperial Institute* contains an article by Mr. F. Evans, the Government Supervisor of Plantations in the Cameroons, dealing with recent developments in agriculture in that part of the former German Colony of the Cameroons which is now being administered under the mandate by Great Britain.

The German authorities, up to 1914, conducted numerous experiments, both at the Government Experiment Stations and on private estates, with a view to improving the out put and quality of the staple products, such as cocoa, rubber, palm oil and various food crops, whilst new crops which seemed likely to succeed in the country were introduced. Marked results were obtained with cocoa, the Cameroons product now being of good grade and taking a high place in the world's markets. This experimental work is being continued so far as the limited staff of the present Agricultural Department admits.

Under the German regime European occupation of land for planting purposes was encouraged and the Government undertook to supply and control all labour both for public works and private enterprise. This resulted in the rapid creation of a sound agricultural industry and the development of large tracts of forest land. Since the British occupation a system of voluntary labour has been initiated and has proved satisfactory, whilst for future development Mr. Evans considers there should be no difficulty in obtaining labour at reasonable rates from the thickly populated districts of the adjoining protectorate of Nigeria. He points out that the soil in the Cameroons is very fertile, the rainfall is well distributed, whilst transport and shipping facilities are good. In addition to the crops now cultivated there are large tracts suitable for tobacco, sugar, bananas and coconuts, and tea should thrive in the hills. The conditions of life generally are unrivalled in West Africa, and the country offers excellent opportunities to men of initiative, who have sufficient capital to engage in tropical agriculture.

CULTIVATION OF GONAKIE IN MAURITANIA.

A recent report made for the Government General of French West Africa, and quoted by the United States Consul at Dakar (Senegal), contained the following information regarding the culture of gonakie in Mauritania :—

Gonakie, or *Acacia adamsonii*, the pods of which produce a tanning material of considerable value, grows only in low humid countries which are inundated a part of the year. For this reason the habitats of gonakie, which are found in southern Mauritania and northern Senegal, where overflows or inundations along the Senegal River are as a rule annual, are more limited than those of the *acacia arabica*, the gum producer. This is due to the fact that the production of pods appears to be dependent upon the duration of the inundations.

Until recent years the pods of the gonakie were used only by the native tanneries. Although the material was relatively abundant, it was collected only in small quantities, as there was little demand for it. In 1916, upon the request of the Government, a small quantity of the pods was collected for the service, Ravitaillement de la Metropole. In 1917 a similar order was issued for 600 or 700 tons, but, as a matter of fact, 1,550 tons were collected.

In 1920 manufacturers of chemical products at Lyons, who were interested in the official analysis of the pods made in that city, instructed their representatives in Senegal and Mauritania to make a study of a proper and stable organization for the collection of the pods. These manufacturers believe that the fruit of the gonakie embodies a material akin to sumac in the nature and quality of its tannins, and that its utilization may be of considerable benefit to tanners, who have been confronted with a scarcity of materials owing to the excessive exploitation of the oaks and chestnuts during the war. Higher prices in Europe for these materials and for the various South American tanning woods are also conducive to the use of gonakie. The exploitation of gonakie has grown rapidly ; in 1921 450 metric tons were collected, 250 tons of which were obtained in Mauritania.

THE POPULATION OF BRITISH MALAYA.

According to the Census taken last year, the total population of British Malaya was 3,358,054, as compared with 2,672,754 in 1911—an increase of 685,300 or 25.6 per cent. Of the total, 2,061,622 were males, and 1,296,432 females. This disparity in the sexes is due to the fact that a large proportion of the population consists of Indian and Chinese male emigrants. Of the 14,954 Europeans, 8,149 lived in the Straits Settlements, and of these 6,231 were resident in Singapore and 1,476 in Penang. There were 5,686 in the Federated Malay States, and 1,119 in the Unfederated Malay States.

The task of the enumerators is attended by more than the ordinary difficulties, and by not a few dangers. In the jungle country houses are few and far between, and in some districts, owing to the fear of tigers, census-takers would not go out unless provided with a bodyguard of two men. A pathetic letter was received from Bentong, in Pahang, from an enumerator who was attacked by an elephant. He had to crawl into a culvert, whence he watched the elephant stamp his bicycle into splinters. In Kedah the work was held up for a month in a whole district by gang robbers, who were terrorising the countryside.

GENERAL NOTES.

ROYAL STATISTICAL SOCIETY.—The Council of the Royal Statistical Society will, in November 1923, award the Frances Wood Memorial Prize, value £30. The Prize will be awarded for the best investigation of any problem dealing with the economic or social conditions of the wage-earning classes. The subject to be chosen by the competitor and to be treated on statistical lines. Those eligible to compete are :—(1) All undergraduates or graduates of not more than three years standing of Universities in the United Kingdom. (2) Non-graduate students who have attended a tutorial class of the Workers' Educational Association for at least two years during the four years preceding the award. (3) Students who have resided, and followed a course of study for at least one year at Ruskin College, in the four years preceding the award. (4) Such other candidates as the Council in their discretion may admit. Theses submitted or intended to be submitted as university exercises, and also published papers, are admissible. Essays (which must be either printed or typed, and accompanied by copies of all statistical tabulations), must be sent to the Honorary Secretaries of the Royal Statistical Society, 9, Adelphi Terrace, W.C.2, not later than 1st July, 1923.

SUGAR PRODUCTION FROM TROPICAL PALMS.—Various palms occurring in the tropics yield a sugary sap which is employed by the natives for making sugar and "toddy," and a summary of information relating specially to the Nipa palm from this point of view is given in the current number of the Bulletin of the Imperial Institute. This palm grows commonly in the muddy estuaries of rivers throughout the Eastern tropics, and is exploited particularly in the Philippine Islands. The sugary juice or "tuba" is obtained by removing the flowering shoot and collecting the juice which escapes from the cut surface. By repeatedly cutting the end of the stalk the flow of juice can be maintained for two or three months, each stalk yielding about 9 or 10 gallons of juice during this period. The juice contains about 15 per cent. of sugar, which can be extracted by means somewhat similar to those used in the manufacture of cane sugar, or if desired, the juice can be fermented for the production of alcohol. It has been estimated that 28 cwts. of sugar or 200 gallons of 95 per cent. alcohol could be obtained annually from an acre of swamp land planted with Nipa palms. The tree occurs over extensive areas in British North Borneo, and the authorities there are considering the question of utilising it as a source of sugar and alcohol, whilst it would appear that there are also possibilities of its being similarly utilised in Malaya.

CANADIAN TIMBER.—The Imperial Institute Advisory Committee on Timbers is conducting an inquiry into the possibility of extending the use in Great Britain of the timbers produced in the various countries of the overseas Empire. The current report deals with timbers from British Columbia and the eastern provinces of Canada, and the attention of the Office of Works has been called to the value of British Columbian Douglas fir, spruce, and hemlock for constructional purposes. As a result of special trials these woods are now included in their official specifications for Government buildings as alternatives to European woods. The Eastern Canadian timbers dealt with comprise soft woods, such as spruce, red, yellow and white pine, and hardwoods, including white birch, rock maple, beech and white elm. The committee consider that the technical qualities of Eastern Canadian timbers are such as to warrant a far larger use of these woods in this country than obtains at present.

IRISH MOSS INDUSTRY AT BREST.—The preparation and exportation of Irish moss is carried on to a considerable extent in the Brest district, writes the United States Consul at Brest. This plant, one of the marine algæ, is gathered by the Brittany peasants along the rocky coast during the summer neap tides. The moss is spread out to dry, being washed by frequent rains. It is then sold to dealers, who pack it in tightly compressed bales after a second cleansing and sorting according to quality. Previous to the war the moss was largely exported to Germany. In 1921 the establishment at Brest, probably the most extensive in France, with a capacity of 300 tons annually, exported to the United States a total of 220 bales, weighing 55,376 pounds.

MEETINGS OF THE SOCIETY.

ORDINARY MEETINGS.

Wednesday evenings, at 8 p.m. :—

FEBRUARY 14.—W. J. REES, Lecturer on Refractories in the University of Sheffield, "The Durability of Refractories." H. J. C. JOHNSTON, President of the Institute of Clay Workers, will preside.

FEBRUARY 21.—C. AINSWORTH MITCHELL, M.A., F.I.C., "Handwriting and its value as Evidence." SIR RICHARD D. MUIR will preside.

FEBRUARY 28.—PROFESSOR W. E. S. TURNER, D.Sc., Head of Department of Glass Technology, The University, Sheffield, "Heat Resisting Glasses." THE HON. SIR CHARLES A. PARSONS, K.C.B., LL.D., D.Sc., F.R.S., will preside.

MARCH 7.—EDWARD PERCY STEBBING, M.A., F.L.S., Professor of Forestry, Uni-

versity of Edinburgh, "The Forests of Russia." THE RIGHT HON. LORD CLINTON, Forestry Commissioner, will preside.

MARCH 14.—SIR WILLIAM WARRENDER MACKENZIE, K.B.E., K.C., President of the Industrial Court, "Industrial Arbitration." LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, will preside.

INDIAN SECTION.

Friday afternoons.

FEBRUARY 16, at 4.30 p.m.—J. T. MARTEN, I.C.S., M.A., Imperial Census Commissioner in India, "The Indian Census of 1921." SIR EDWARD A. GAIT, K.C.S.I., C.I.E., Member of the India Council, will preside.

APRIL 6, at 4 p.m.—GEOFFREY ROTHE CLARKE, C.S.I., O.B.E., I.C.S., Director-General Posts and Telegraphs, India, "Postal and Telegraph Work in India." LORD MONTAGU OF BEAULIEU, K.C.I.E., C.S.I., will preside.

JUNE 15, at 4.30 p.m.—SIR JOHN H. MARSHALL, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture).

DOMINIONS AND COLONIES SECTION.

Tuesday afternoon at 4.30 o'clock.

MARCH 6.—Major E. A. Belcher, C.B.E., Assistant General Manager, British Empire Exhibition, "The Dominion and Colonial Sections of the British Empire Exhibition, 1924." THE RT. HON. L. S. AMERY, M.P., will preside.

DOMINIONS AND COLONIES AND INDIAN SECTIONS. (Joint Meetings).

Tuesday or Friday afternoons at 4.30 o'clock.

MARCH 16.—Lieut.-Col. SIR LEONARD ROGERS, C.I.E., F.R.S., F.R.C.P., F.R.C.S., Physician and Lecturer, London School of Tropical Medicine, "Recent Advances towards the Solution of the Leprosy Problem."

APRIL 20.—SIR RICHARD A. S. REDMAYNE, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S., "The Base Metal Resources of the British Empire."

MAY 1.—L. GUY RADCLIFFE, M.Sc. (Tech.), F.I.C., "The Essential Oils of the British Empire."

Dates to be hereafter announced:

WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Recent Developments in Surface Combustion."

MAURICE DRAKE, "The Development of Mediæval Technique in Stained Glass Windows."

EDWARD PARNELL, "The Resources and Trade of Sarawak."

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

HENRY P. STEVENS, M.A., Ph.D., F.I.C., "The Vulcanisation of Rubber." Three Lectures. February 5, 12, 19.

SYLLABUS.

LECTURE II. February 12th.—Methods of vulcanisation. Heat treatment. Vulcanising agents. Cold cures. Accelerators. Vulcanisation of rubber sols and gels.

LECTURE III. February 19th.—Measurement of vulcanising effort. Load-stretch curves. Mineral compounding ingredients. Theories of vulcanisation.

J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards, "Length Measurement." Three Lectures. March 5, 12, 19.

E. KILBURN SCOTT, Assoc.M.Inst.C.E., M.I.E.E. "The Fixation of Nitrogen." Three Lectures. April 9, 16, 23.

HOWARD LECTURES.

Monday evenings at 8 o'clock.

STANLEY S. COOK, "Recent Improvement in Steam Turbines." Three Lectures. April 30, May 7, 14.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, FEBRUARY 12 .. Geographical Society, 135, New Bond Street, W., 8.30 p.m. (1), Mr. H. S. J. B. Philby, "The North Arabian Desert." (2), Major A. L. Holt, "The Future of the Desert."

Surveyors' Institution, 12, Great George Street, S.W., 8 p.m.

Brewing, Institute of (London Section), at the Institute of Chemistry, 30, Russell Square, W.C., 8 p.m. Messrs. H. Langwell and H. L. Hind, "Cellulose Fermentation—The Utilisation of Spelt, Hops and Grains."

University of London, University College, Gower Street, W.C., 5 p.m. Mr. H. C. Thornton, "Conditions affecting Bacterial Activities in the Soil, activities connected with the Intake of Protein Building Materials." At King's College, Strand, W.C., 5.30 p.m. Rev. C. F. Rogers, "Ecclesiastical Music." (Lecture II.) 5.30 p.m. Professor R. Dyboski, "Poland." (Lecture IV.)

East India Association, Caxton Hall, Westminster, S.W., 3.30 p.m. Sir Robert W. Gillan, "The Present and Future Management of Indian Railways."

TUESDAY, FEBRUARY 13 .. Petroleum Technologists, Institution of, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.30 p.m. Mr. G. W. E. Gibson, "Some Practical Notes on Oil Pumping."

Royal Institution, Albemarle Street, W., 3 p.m. Professor A. C. Pearson, "Greek Civilisation and To-Day." (Lecture I.)

Metals, Institute of (Scottish Section), 35, Elmbank Crescent, Glasgow, 7.30 p.m. Mr. J. A. Sillars, "Some Phases of Lead Manufacture."

Colonial Institute, Victoria Hotel, Northumberland Avenue, W.C., 8.30 p.m. Sir Campbell Stuart, "Canada and the Empire."

Photographic Society, 35, Russell Square, W.C., 7 p.m. Mr. A. E. Bawtree, "Dangers to Eyesight in Domestic Electric Lighting, and the Kinema Picture Display."

Transport, Institute of, at the Institute of Electrical Engineers, Savoy Place, Victoria Embankment, W.C., 5.30 p.m. (Graduate Section), Mr. B. Wagenrieder "Railway Rules and Regulations."

University of London, University College, Gower Street, W.C., 5.30 p.m. Mr. J. H. Helweg, "Contemporary Danish Literature." (Lecture II.) 5.30 p.m., Mr. N. H. Baines, "The Roman Empire in the Fourth Century." (Lecture II.) At King's College, Strand, W.C., 5.30 p.m. Miss H. D. Oakley, "The Enigma of Socrates." (Lecture IV.) 5.30 p.m., Sir Bernard Pares, 'Contemporary Russia from 1861." (Lecture IV.)

Marine Engineers, Institute of, 85, The Minories, Tower Hill, E., 6.30 p.m. Mr. T. D. Madsen, "Internal Combustion and Economy."

Asiatic Society, 74, Grosvenor Street, W., 4.30 p.m. Mr. E. J. Holmyard, "Arabian Alchemy and Chemistry."

WEDNESDAY, FEBRUARY 14 .. Public Health, Royal Institute of, 37, Russell Square, W.C., 4 p.m. Dr. A. H. Gosse, "Public Health Aspects of Pulmonary Tuberculosis."

Industrial League and Council, Caxton Hall, Westminster, S.W., 7.30 p.m. Sir Lynden Macassey, "Home and International Labour."

University of London, University College, Gower Street, W.C., 5 p.m. Mr. D. W. Cutler, "Protozoa of the Soil." 5.30 p.m., Mr. G. A. Stephen, "Modern Machine Binding." 3 p.m., Professor E. G. Gardner, "Dante in his Works." (Lecture II.) 5.30 p.m., Mr. J. C. Gröndahl, "The Work of Wergeland." (Lecture II.) 5.30 p.m., Professor P. Geyl, "Charles I. and Charles II. and the Princes of Orange." (Lecture II.) 5 p.m. Mr. P. Leon, "The Theory of Beauty." (Lecture I.)

At King's College, Strand, W.C., 5.30 p.m. Dr. D. Scott, "The Succession of Floras in the Past."

THURSDAY, FEBRUARY 15 .. Aeronautical Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.30 p.m. Wing-Commander P. R. Cave-Brown-Cave, "The Practical Aspects of the Sea Plane."

Royal Society, Burlington House, Piccadilly, W., 4 p.m.

Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.

Linnean Society, Burlington House, Piccadilly, W., 5 p.m.

Chemical Society, Burlington House, Piccadilly, W., 8 p.m. (1), Mr. E. F. Morris, "Calculation of Fundamental Constants." (2), Mr. A. C. Chapman, "Spinacene: Its Oxidation and Decomposition." (3), Messrs. R. H. Pickard and H. Hunter, "Investigations on the dependence of Rotatory power on Chemical Constitution. Part XIX., The Rotatory and Refractive dispersion of d-y-nonyl nitrite. (4), Mr. H. Hunter, "Investigations on the dependence of Rotatory Power on Chemical Constitution. Part XX. The rotatory dispersive powers of oxygen compounds containing the secondary octyl radicle."

Mining and Metallurgy, at the Geological Society, Burlington House, Piccadilly, W., 5.30 p.m.

Child Study Society, at the Royal Sanitary Institute, 90, Buckingham Palace Road, S.W., 6 p.m. Miss Richardson, "Monsieur Coué and his Work."

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C., 6 p.m. Mr. J. Rosen, "Some Problems in High Speed Alternators and their Solution."

British Decorators, Institute of, Painter's Hall, Little Trinity Lane, E.C., 7.30 p.m. Mr. W. B. Cantrill, "A Pilgrimage to the Hill Towns of Umbria."

Camera Club, 17, John Street, Adelphi, W.C., 8.15 p.m. Major F. C. Laws, "Progress in Aerial Photography."

London County Council, at the Geffrye Museum, Kingsland Road, E., Mr. P. A. Wells, "Jacobean and Stuart Furniture."

Transport, Institute of (N. Western Section), The University, Liverpool, 6 p.m. Mr. H. H. Gordon, "Some Factors relating to the Growth of Passenger Traffic, and means of meeting the demand in large cities."

Royal Institution, Albemarle Street, W., 3 p.m. Mr. B. M. Jones, "Recent Experiments in Aerial Surveying." (Lecture I.)

University of London, University College, Gower Street, W.C., 5.30 p.m. Professor W. Barthold, "The Nomads of Central Asia." (Lecture V.) 5.30 p.m., Mr. C. Pellizzi, "Vincenzo Gioberti." (In Italian). 6.30 p.m. Mr. J. Björkhagen, "Swedish Literature in the XVIII. Century." (Lecture III.) 5.15 p.m. Mr. J. E. G. Montmorency, "Distribution of Customary Law in England and France."

At King's College, Strand, W.C., 5.30 p.m., Dr. O. Vocadio, "Modern Czech Novelists." (Lecture IV.) 5.30 p.m., Mr. L. Wharton, "Slowacki and the King Spirit."

At the London Hospital Medical College, Mile End, E., 4.30 p.m. Mr. W. A. M. Smart, "The Mathematical Basis of Physiological Problems." (Lecture V.)

Photographic Society, 35, Russell Square, W.C., 7 p.m. Mr. H. Stevens, "A Photographic Pot-Pourri." (Special Lantern Lecture.)

FRIDAY, FEBRUARY 16 .. Royal Institution, Albemarle Street, W., 9 p.m. Dr. A. V. Hill, "Muscular Exercise."

Dyers and Colourists, Society of (Local Section), College of Technology, Manchester, 7.15 p.m. Lecture by Dr. F. M. Rowe.

University of London, University College, Gower Street, W.C., 5.15 p.m. Mr. P. A. Scholes, "The Place of Music in the Education of the Future." At King's College, Strand, W.C., 5.30 p.m., Dr. R. W. Seton-Watson, "Serbia and the Jugo-Slav Movement." (Lecture V.) 5.30 p.m. Dr. Scripture, "Shakespeare's Verse in the Light of Experimental Phonetics."

Geological Society, Burlington House, Piccadilly, W., 3 p.m. Annual General Meeting. President's Address.

Photographic Society, 35, Russell Square, W.C., 8 p.m. Mr. J. C. Warburg, "Possibilities in Colour Photography."

SATURDAY, FEBRUARY 17 .. Royal Institution, Albemarle Street, W., 3 p.m. Sir Ernest Rutherford, "Atomic Projectiles and their Properties.' (Lecture I.)

London County Council, at the Horniman Museum, Forest Hill, S.E., 3.30 p.m. Dr. F. A. Bather, "A Limestone Cliff and the Animals that built it."

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FRIDAY, FEBRUARY 16, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.(2

NOTICES.

NEXT WEEK

MONDAY, FEBRUARY 19th, at 8 p.m. (Cantor Lecture.) HENRY P. STEVENS, M.A., Ph.D., F.I.C., "The Vulcanisation of Rubber." (Lecture III.)

WEDNESDAY, FEBRUARY 21st, at 8 p.m. (Ordinary Meeting.) C. AINSWORTH MITCHELL, M.A., F.I.C., "Handwriting and its Value as Evidence." SIR RICHARD D. MUIR, Senior Counsel to the Treasury, Central Criminal Court, will preside.

CANTOR LECTURE.

On Monday evening, February 12th, DR. HENRY P. STEVENS, M.A., F.I.C., delivered the second lecture of his course on "The Vulcanisation of Rubber."

The lectures will be published in the *Journal* during the summer recess.

TENTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 7th, 1923; SIR ROBERT A. HADFIELD, Bt., D.Sc., F.R.S., in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Crawford, Lieut.-Colonel W. L., D.S.O., Saklaspur, Hassan, India.
Ely, Professor John Andrews, Shanghai, China.
Macdonald, Mrs. L. M. Montgomery, Leaskdale, Ontario, Canada.
Morse, Arthur Hyatt, A.M.I.E.E., Montreal, Canada.
Moyer, Professor James Ambrose, Boston, U.S.A.
Smith, John Frederick, Headingley, Leeds.
Smythe, Albert Ernest Stafford, Toronto, Canada.

The following candidates were duly elected Fellows of the Society:—

Amin, Bhailal Dajibhai, B.A., M.S.C.I., Baroda, India.
Coubrough, Anthony Cathcart, C.B.E., M.A., B.Sc., M.I.E.E., M.I.Mech.E., Calcutta, India.
Kitchell, Major Joseph Gray, New York City, U.S.A.
Thomson, James B., Vancouver, B.C., Canada.

A paper on "Electrical Resistance Furnaces and their Uses," was read by MR. CHARLES R. DARLING, F.Inst.P., F.I.C.

The paper and discussion will be published in a subsequent number of the *Journal*.

PROCEEDINGS OF THE SOCIETY.

INDIAN SECTION.

19TH JANUARY, 1923.

THE RT. HON. VISCOUNT PEEL, G.B.E., Secretary of State for India, in the Chair.

The following paper was read:—

A CLASH OF IDEALS AS A SOURCE OF INDIAN UNREST.

By THE EARL OF RONALDSHAY, P.C., G.C.S.I., G.C.I.E.,
Governor of Bengal, 1917-22.

It is no part of my purpose this afternoon to attempt to assess the achievements of Great Britain in India. That is a task which may safely be left to the historian of the future; and with the mere observation that the people of this country have little to fear from the verdict of history, I leave it to him, and pass on to a task which, in the meantime, may be pursued with greater present profit, namely, that of attempting to see things from the Indian point of view.

There is certainly a good deal that is perplexing in the situation in India at the present time. I am profoundly convinced that the judgment of history will be that the work of Great Britain in India, whether judged from a moral or a material point of view, has been of benefit to the Indian people; that the accounts when they are finally made up and audited will show a large credit balance. Yet I find in the

India of to-day an atmosphere heavily charged with racial animosity in which every act of the Government is suspect, and in many quarters is incontinently condemned, not on its merits, but for no other reason than that it is the act of an authority which is partly British in personnel and preponderatingly British—and this is, perhaps, the head and front of its offending —in character and outlook. Confronted with such a state of affairs, one naturally asks, Why? The most obvious answer to that question is, I think, on account of the economic and political dislocation produced by the world war. But the most obvious is not necessarily the only, or even the most important, answer to the question. I do not for a moment under-estimate the importance, as a factor making for unrest, of the rise in prices which has taken place in India, in sympathy with the upward movement of prices throughout the world, and which has reacted so unfavourably upon the educated middle classes, from which the bulk of the politically minded is drawn; or of the Turkish imbroglio which has fired the dormant fanaticism of the Muhammadans, hitherto one of the more stable elements in the Indian polity. But these are not fundamental sources of unrest, for they are transient in nature. The economic strain may be eased; a solution of the Turkish problem may be found. Are there causes of Indian unrest more fundamental than these? And if so, what are they? I think that there are, and the source of unrest which seems to me to be one of fundamental importance is the heat generated by the clash of two conflicting ideals, the offspring of two different outlooks upon the universe, those of the East and the West respectively.

The civilisation and culture of a people are the outward manifestations of their intellectual and emotional outlook upon their environment; distinctive civilisations indicate distinctive modes of thought. If two such distinctive civilisations come into contact with one another, and if—intentionally or otherwise—one tends to absorb the other, then there is war, not necessarily on the physical, but on the mental plane. If such a situation has arisen in India, then without looking further for causes, we shall find ourselves in the presence of a fundamental cause of unrest. Let us examine the present position in India from this standpoint.

When the British came to India, they found a people distracted and exhausted by internal dissension and incapable, consequently, or, at least, indisposed to offer any strong resistance to the virile civilisation which they carried with them from the West. On the contrary, a class of Indian sprang up which adopted indiscriminately everything Western, the bad along with the good. It became the fashion amongst a certain section of the educated middle classes in Bengal, during the middle of last century, to mimic the Englishman in everything, and to adopt his habits both good and bad. Thus we find, in the autobiography of a well-known Bengali gentleman of the 19th century, Babu Raj Narain Bose, the following comment:—"It was a common belief of the alumni of the college, that the drinking of wine was one of the concomitants of civilisation"; and he adds:—"At the beginning of 1884 I became dangerously ill, and the cause of it was excessive drinking." A graphic picture of the state of affairs at that time has been painted by another Bengali gentleman, the Rev. P. C. Mazumder, who was himself a college student at this critical period in the history of Bengal. "Sanskrit, Persian and Arabic," he declares, "held in such supreme reverence but a few years before as the only source of wisdom were (now) looked down upon with supreme contempt." The young men of the day sought for inspiration in "the wide unclean waters of inferior works of English fiction," and following hard upon this new spirit of contempt for their own past, came religious scepticism which eat its way deep into the moral fibre of young Bengal. "The ancient scriptures of the country, the famous records of the spiritual experiences of the great men of numerous Hindu sects, had long since been discredited. The Vedas and the upanishads were sealed books. . . . . . The whole religious literature of ancient India presented an endless void." And the result is painted with an unsparing hand. "All faith in morality and religion every day became weaker, and tended to decay. The advancing tide of a very mixed civilisation with as much evil as good in it, the flood of fashionable carnality threatened to carry everything before it." Such descriptions coming, as they do, from the pens of men who wrote of what they themselves saw and experienced, leave little room for doubt

as to what was happening. Young Bengal was rapidly becoming both demoralised and denationalised. Still, it must be borne in mind that however prominent a place young Bengal occupied in the public eye, it constituted but a minute fraction of the population. It was like the foam caught by the wind on the surface of the sea. Beneath the surface still rolled the deep, placid waters of Indian life; and a reaction was bound to come. Such a reaction is, as a matter of fact, now in full swing. And just as during the last century the pendulum swung far over towards Westernism, so now it has swung back far in the opposite direction.

The motive force behind the swing of the pendulum is, surely, sufficiently plain. It is fear—fear lest before the triumphant assertiveness of Western civilisation all that is essentially and distinctively Indian is doomed to perish and utterly to disappear. With the object lesson of young Bengal of the 19th century before one, this fear is at least intelligible, and we recognise at once the presence of that struggle on the mental plane of which I spoke a few minutes ago. Nothing strikes one so much at the present time as the extreme sensitiveness of Indians in their relations with Europeans. It is precisely what one would expect in the case of a people afflicted, whether consciously or not, by fear of the kind which I have described. And if we are to dry up this potent source of racial animosity, we must make a supreme effort to restore the confidence of Indians in two things—in the integrity of our own intentions not to thrust upon them a civilisation which they do not desire, and in the capacity of their own civilisation to exact our sympathetic interest and respect. If we are to succeed in such an effort, we must all of us, in whatever capacity we come into contact with India, whether as officials, or as business men, or as mere visitors, make a real endeavour to appreciate the Indian point of view. I do not underestimate the difficulty of doing so; for the Indian view point differs widely from our own, as was strikingly demonstrated, for example, by the manner of Mr. Gandhi's recent campaign against the Government. From the very beginning of his crusade he insisted that suffering and renunciation were the weapons with which those who served under his banner must fight. "He who runs may see," he declared in an open letter to H.R.H. the Duke of Connaught, "that this is a religious purifying movement"; and addressing himself on another occasion to the students of Bengal, he said in the course of a speech delivered in Calcutta: "I am not ashamed to repeat before you who seem to be nurtured in modern traditions—who seem to be filled with the writing of modern writers—that this is a religious battle. I am not ashamed to repeat before you that this is an attempt to revolutionise the political outlook—that this is an attempt to spiritualise our politics." It was natural enough that when the result of the movement which he had inaugurated was seen to be a succession of outbreaks of mob violence, his appeals to soul force and his denunciation of physical force should excite the derision of his opponents. But quite apart from this, the plan of his campaign was one which was puzzling to the Western mind. An anonymous writer in the *Englishman* newspaper who professed his faith in the methods of Mr. Gandhi stated that conversations which he had held with English people, as also the comments which he had read in the English Press, satisfied him that Europeans did not in the least realise what was meant by *Satyagraha*. He explained that the reason why Mr. Gandhi wanted those who desired to join him "to give up connexion with the Government, and worldly affairs, and the lust after money and mechanical contrivances, is because these things interfere with single-mindedness." And he added: "*Satyagraha* is soul force exerted by a multitude of people all wishing hard for what they desire. In order to be in a position to wish hard they must divest themselves of their worldly possessions and of their earth-bound desires." The idea is certainly one with which the Western mind is little familiar. Nevertheless, I do not think that it ought to have caused surprise to any one who knew anything of Indian thought, for it rests upon an Indian belief of immemorial antiquity, namely, that power can be acquired by the practice of renunciation and austerities. The ancient literature of India is strewn with examples of the efficacy of self-mortification as a means of acquiring power. A famous figure who appears in the Vedas, in both the great epics, the Mahabharata and the Rāmayāna, as also in the Purānas, is the hero of a story which may, perhaps, be

described as the classic example of this practice. The figure is Visvamitra, a king, and the story is that of a fierce and sustained conflict between him and Vasishta, a Brahman. It can be recalled in a few words. The cupidity of Visvamitra was excited by a "cow of plenty" in the possession of Vasishta, which he determined to acquire. Failing to obtain the animal by force, he abandoned his kingdom and retired to the Himalayas, where he lived the life of an ascetic, subjecting himself to the severest austerities. His earliest reward came in the shape of an armoury of celestial weapons presented to him by the great god Mahadeva. With these he hurried back to the conflict with Vasishta, but was again defeated by the powerful priest. and returned to the Himalayas and his self-imposed austerities with a view to acquiring further reserves of soul force. We need not follow him through the thousand year periods of self-mortification which he indulged in, obtaining with each successive period greater power and being offered by the gods steadily increasing rewards. In the end the "cow of plenty" which had been the source of all the trouble pales into insignificance before the prodigious developments arising out of Visvamitra's sustained practice of intense austerities; and it becomes a question of the continued existence of the universe. The supernatural power acquired by him does, indeed, become a menace to gods and men, so much so that the former proceed to Brahma to lay before him the critical state of affairs with which they find themselves confronted. "The great *muni* Visvamitra," they declare, "has been allured and provoked in various ways, but still advances in his sanctity. If his wish is not conceded, he will destroy the three worlds by the force of his austerity. All the regions of the universe are confounded, no light anywhere shines; all the oceans are tossed and the mountains crumble, the earth quakes and the wind blows confusedly." The heavenly deputation is successful in impressing Brahma with a sense of the urgency of the matter, and, accompanied by the heavenly host, he himself approaches the terrible ascetic and, pronouncing a blessing upon him, hails him as *Brahman-rishi*. Visvamitra the king having thus compelled the gods to grant him the supreme rank of Brahmanhood, desists from the course which through successive millenniums he had been following to the danger of the universe.

You will perceive that viewed in the light of Indian thought, Mr. Gandhi's doctrine of soul force, which to many Westerners appeared to be a meaningless fad, becomes not only intelligible, but perfectly natural. There are, indeed, striking points of resemblance between the story of King Visvamitra and that of Mr. Gandhi. The original cause of Visvamitra's campaign was a comparatively small thing, namely, Vasishta's "cow of plenty." Similarly, the original cause of Mr. Gandhi's campaign was a comparatively small thing, namely, a legislative enactment known as the Rowlatt Act. And just as in the former case the "cow of plenty" lost all importance in face of the shattering developments to which Visvamitra's action gave rise, so in the latter case did the Rowlatt Act lose all importance in face of the convulsion which Mr. Gandhi's action produced. There is a *dénouement* to the story of King Visvamitra; but the story serves as the prologue of my discourse, and I shall return to the *dénouement* later.

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Now, let us examine the gulf which yawns between the ideals of India and of Europe as pictured by Indians in its crudest colouring. For the most extreme view we must go to Mr. Gandhi himself and a few of his closest followers. In the opinion of Mr. Gandhi the civilisation of the West, or that which he prefers to call modern civilisation, is grossly material, while that which has been evolved in India is of a higher and more spiritual type. "The tendency of Indian civilisation," he tells us, "is to elevate the moral being, that of Western civilisation is to propagate immorality. The latter is godless; the former is based on a belief in God." This is Mr. Gandhi's considered opinion, for the language which I have quoted does not occur in a speech in delivering which the speaker might in the fervour of the moment have been led into exaggeration, but in a deliberate expression of his views in book form, a second edition of which was issued with his approval in 1919.* These being his views, it is not surprising to find him describing modern civilisation in the speech made in Calcutta on January the 27th, 1921, to which I have already referred, as "the worship of the material; the worship of the brute in us; in short, unadulterated

* "Indian Home Rule," by M.K. Ghandi.

materialism;" or exhorting his audience "to shun it at all costs."

I have given Mr. Gandhi's view, partly, because if we are to understand the Indian point of view we must be seized of it in its most extreme form, and, partly, because Mr. Gandhi could never have acquired the dominant position which he has occupied among his countrymen in recent years, unless the views which he held had commanded a very appreciable measure of assent. The task which I now propose to undertake is to attempt to assess the extent amongst Indians generally of the belief which Mr. Gandhi holds, that the civilisation of the West is dangerously materialistic, while that of India is of a more spiritual type. If I am able to show that this belief is widely held, I shall claim to have given good reason for my contention, that a potent cause of Indian unrest is fear lest the continued domination of the West will result in the smothering of the ancient spirituality of India by the aggressive materialism of Europe.

Such an investigation can best be undertaken by examining movements in different spheres of human activity and endeavouring to analyse the motive power behind them. In the political sphere I propose to take the revolutionary movement in Bengal, because it preceded Mr. Gandhi's non-co-operation movement and cannot, therefore, have been influenced by it. If behind this movement we discover motives of the same kind as those behind Mr. Gandhi's later movement, we shall obviously have good grounds for holding that these motives must be tolerably widespread. All the more so in that the centre of Mr. Gandhi's influence was in the West of India, while that of the Bengali revolutionaries was in the East. I shall then examine the present-day trend of thought amongst Indians in the matter of education, with a view to ascertaining whether the Western system of education which we have established in India is meeting with serious challenge; and, finally. I shall endeavour to conduct a similar investigation in the non-political sphere of art. That is to say, I shall ask these questions: Is there any characteristic of Indian Art which can be said to differentiate it from the art of the West, and, if so, is there any sign of rebellion on the part of the present-day exponents of Indian Art against its subjection to the canons of the Art of Europe?

First as to the revolutionary movement. It was active in Bengal for more than a decade from 1906 onwards, and it was responsible for many deaths and much destruction of property. There was much in it that was sordid, much that was horrible, much that constituted an unblushing outrage on morality, as there is in all movements that adopt the cult of the revolver and the bomb. But I do not wish to dwell upon this aspect of it. I am merely concerned in the present connexion, to search for the motive behind all the ugly manifestations for which the movement was responsible. And I shall have little difficulty in showing, I think, that in the opinion of Indians themselves, at any rate, there was behind it all a great, if perverted, ideal. Let me quote from a memorandum drawn up by an Indian gentleman who was placed by circumstances in a position in which he was in the confidence of some, at least, of those who were connected with the movement.* The document in question purports to be an explanation of "the storm that had been gathering in the heart of India for the best part of a decade and would demand immediate attention at the close of the war." After referring to the anger aroused in the heart of Bengal by the failure of the agitation to prevent the partition of the province, the writer speaks of Arabinda Ghose and of the secret of the influence which he exercised over the young men of Bengal. The passage is worth quoting, both on its own account and because of the light which it sheds on the question which I am considering. Of Arabinda Ghose's writings, he says:—"The aspiration of young India was in them; . . . an exultation, an urgency, a heartening call on his countrymen to serve and save the Motherland, an impassioned appeal to their manhood to reinstate her in the greatness that was hers. Had she not once been the High Priestess of the Orient? Had not her civilisation left its ripple mark on the furthermost limits of Asia? India still had a soul to save, which the parching drought of modern vulgarity threatened daily with death; she alone in a pharisaical world, where everyone acclaimed God in speech and denied Him in fact, offered Him the worship of her heart. . . . . The saving wisdom was still in the land which taught man how to

*The author of the memorandum was Mr. B. C. Chatterjee, barrister-at-law.

know and realise his God—the wisdom which had been gathered and garnered in their forest homes by her priest-philosophers, the builders of the Vedas, the thinkers of the Upanishads, the greatest aristocrats of humanity that had ever been.'' And then came a cry of anguish, a cry which sprang, surely, direct from the writer's heart: ''But how should the culture of the soul survive in the land where a shifting materialism was asserting itself under the ægis of English rule? Had not the fools and the Philistines, whose name was legion—the monstrous products of a soulless education nourished on the rind of European thought—already begun to laugh at their country's past? And dared to contemn the wisdom of their ancestors? Was India to deform herself from a temple of God into one vast inglorious suburb of English civilisation? . . . This doom which impended over the land must be averted. India must save herself by ending the alien dominion which had not only impoverished her body, but was strangling her soul.''

Next we are referred to another prophet of the new nationalism, Barindra Kumar Ghose, who appealed to his countrymen with a fire and passion even exceeding that of his brother. His appeal was for men, ''hundreds of thousands of them, who were ready to wipe out with their blood the stain of India's age-long subjection.'' Unless they bestirred themselves they would become a race of slaves. ''And then,'' —I quote from the memorandum once more—''good-bye for ever to the India of Valmiki and Vyasa, of the Vedas and Vedãnta, from whose sacred soil had sprung Lord Krishna and Gautama Buddha. Farewell, Priestess of Asia, mistress of the eastern seas, Temple of Nirvana, to which pilgrims journeyed from Palestine and Cathay.''

By temperament the people of Bengal are emotional. Appeals such as these were well calculated to sweep them off their feet. Such fiery oratory, to quote from the memorandum, ''smote on the heart of the people as on a giant's harp, awakening out of it a storm and a tumult such as Bengal had never known through the long centuries of her political serfdom.''

I have placed before you the motive behind the revolutionary movement in Bengal as pictured by the Indian himself. Did time permit I could adduce much evidence to show that whatever may have been the motive of those who actually organised the deeds of violence, large numbers of those who were persuaded to join the movement were young idealists who saw it through the same spectacles as those of the writer of the memorandum from which I have given extracts. I must content myself with a very brief indication of the nature of the evidence which exists. It was stated in the revolutionary literature, for example, that SALVATION was the goal at which all must aim, and that salvation was not possible without a revival of the ancient spiritual culture of the Hindus in all its phases. The attention of the recruit was to be directed to the nature of man, his existence and the cause thereof, his origin and the reason for his life upon this earth, his relation and duty to the world and his environment; later he was to be asked to ponder upon the duty which he owed to India. A picture of India past, India present and India future in its three phases—political, social and religious—was to be put before him; and it was to be impressed upon him that life was a mission and duty the highest law. Finally, he was to be urged to cultivate a yearning for unity, moral and political, founded upon some great organic, authoritative idea—the love of country, the worship of India, the sublime vision of the destiny in store for her, leading the Indians in holiness and truth. Then, again, the use made by the revolutionary party of the Bhagavad Gita, the most universally treasured, perhaps, of all the Hindu scriptures, is significant. It played a prominent part in the ceremonies of the revolutionary organisations, and the teaching of certain of its texts removed from their context was represented as giving sanction to deeds of violence. The use thus made of a scripture containing teaching so lofty as that of the Gita provides one of the most tragic of the many examples, surely, with which the history of mankind abounds of religious zeal perverted to irreligious ends.

Finally, let me quote from a petition which I received from a young Indian desirous of unburdening his soul on the subject of his connexion with the revolutionary movement. Reflection had led him to the conclusion that the methods adopted were doomed to failure and that even if they were likely to be successful, ''India of all countries of the world should

never, with that great mission of hers—the spiritual uplift of the world—take to them.'' He explained frankly his reason for joining the revolutionary movement. He had been led to believe, he said, that by the emancipation of India by means of revolution, the Hindu religion could break its binding fetters and again flourish in its past glory, vivified and brightened a thousandfold, and, triumphing over the world, bring about its spiritual regeneration.

I have said enough, perhaps, to show that behind the revolutionary movement in Bengal there was a vague ideal; a motive force similar in kind to that behind the later movement of Mr. Gandhi.

Now let us take a brief glance at recent movements in the educational world. One has no difficulty in discovering that there is dissatisfaction in India with the educational system. It is not so easy to discover precisely what it is that Indians desire to see taking its place. During recent years there has been a very emphatic demand for vocational education. The driving force behind this demand has been the economic strain upon the middle classes; just as economic necessity was one of the determining factors in the widespread establishment of the existing system. The existing system with its strong literary bias is now turning out a supply of graduates and undergraduates in arts which exceeds the demand; hence the agitation for courses of a more practical type. The demand for medical training in Bengal, for example, is clamorous and wide-spread. It is, however, necessity rather than predilection that is the determining factor in this movement. The existing system is condemned by Indian sentiment on the score of its Western bias. The medium of instruction is English, the education itself is secular, religious teaching finding no place in the curriculum, the learning imparted is that of the West. It is on these grounds that, at times of political excitement, it is condemned. Both during the anti-partition agitation in Bengal and during Mr. Gandhi's recent campaign, a fierce attack was made upon schools and colleges on these grounds, and students were persuaded to leave them *en masse*. The extreme view has been voiced repeatedly of late; it was put concisely by Mr. Jitendra Lal Bannerji, a prominent follower of Mr. Gandhi, when, in a speech delivered in Calcutta less than two years ago, he said: ''English learning may be good, English culture may be good; their philosophy may be good; their Government, their law, everything may be good, but each one of these but helps to rivet the fetters of our servitude. Therefore I say to the English, good as these things may be, take them away; take them away beyond the seas, beyond the rivers far off to your Western home, so that we and our generation may have nothing to do with them—may not be accursed with the contamination either of your goodness or of your evil. Leave us to ourselves."

The speaker is an apostle of non-co-operation in its most extreme form. But it would be a mistake to suppose that the sentiments which he expressed are nothing more than the froth and bubble upon waters lashed to fury by a political storm. They are deep rooted in the soil of India; and there are many Indians who are far from being hostile to the British connexion who ardently desire to see a more distinctly Indian orientation given to the education imparted to their people.

The views of such persons were voiced by Sir Rashbehary Ghose in the course of a speech delivered in 1911 in support of the establishment of a Hindu university. ''Education,'' he said, ''must have its roots deep down in national sentiment and national tradition. . . . . We are the heirs of an ancient civilisation, and the true office of education ought to be the encouragement of a gradual and spontaneous growth of the ideals which have given a definite mould to our culture and our institutions. . . . . In our curriculum, therefore, Hindu ethics and metaphysics will occupy a foremost place, the Western system being used only for purposes of contrast and illustration. Special attention will also be paid to a knowledge of the country, its literature, its arts, its philosophy and its history.'' The Hindu university in support of which Sir Rashbehary Ghose spoke, is now an established fact. Situated at Benares, the holy city of the Hindus, it stands a living witness to the strength of the sentiment to which I have referred. Nor is it the only one. Other such witnesses which immediately come to mind, are the educational institutions of the Arya Samaj, notably the Gurukul at Hardwar; the school founded by Sir Rabindra Nath Tagore at Bholpur; and the Hindu Academy at Daulatpur. I wish that time permitted

me to give you a description of these places, for they are all of absorbing interest, and throw much light upon the matter which I am discussing. But it would be impossible to do justice to them in the time at my disposal, and I must content myself with a brief reference to one of them. I select the Hindu Academy at Daulatpur, partly because it is the least known, and partly because I have visited it comparatively recently myself.

The idea of the institution was explained to me by the little band of enthusiastic workers to whom it owed its existence. They told me how, nearly twenty years before, they had been struck with the grave defects of an educational system under which the teaching was wholly divorced from religion. Was it not possible, they asked themselves, to bring about a harmonious combination of the religion and philosophy of India with the arts and sciences of the West ? And for the answer they pointed to the buildings all round; the chemical and physical laboratories; the simple hostels half seen amid the rich vegetation of Bengal; the playing-fields; and, last but not least, the temple, on the floor of whose quiet and shaded portico a Sanskrit pundit was expounding the shastras to an eager but reverent group of boys. Classes are held in the subjects of the ordinary university course; but side by side with these, instruction is given in such subjects as are taught in the Sanskrit tols; and the influence of the teaching of what may be described as the "Indian side," is apparent in the whole atmosphere of the institution. Of this one became aware as one passed from its classrooms to its simple hostels and chatted to the teachers and the taught. And standing in converse with the earnest band of workers in the shadow of the temple court yard, the hush of the tropic noon scarcely broken by the soft murmur of the Bhairab river pursuing its eternal journey from the mountains to the sea, with the calm features of the *acharya* and his fellow pundits outlined against the gloom which brooded like a softly draped figure of Night behind the open door-way of the inner shrine, it was easy to believe that the hope of its founders had been realised—that the college had indeed "grown under the shade of the temple," and that teachers and students had found "in their pursuit of knowledge, the worship of God."

I now come to the third field of human activity which I set out to examine, namely, that of art, by no means the least important in this connexion, since the art of a people may be said to be their attempt to give sensible expression to their soul. I am going to be rash enough to indulge in a generalisation. I am going to suggest that the outstanding distinction between the art of India and that of Europe is the idealism of the former as compared with the realism of the latter. The generalisation is subject to very large qualifications, and I am all the rasher in making it because I have not the time to set forth the qualifications. Moreover, it is difficult to convey in a few sentences what one means by the idealism of Indian Art. It is most pronounced in the religious art of the country. And if you were to ask the Indian artist what exactly was his aim, he would tell you, I think, that he was not concerned to produce a faithful likeness of his objective surroundings, but rather to catch the reality lying behind the appearance of things. His art in other words is a faithful reflection of the idealism of his philosophy. The world perceived by the senses is unreal; it is a veil behind which reality lies hidden. And when it is realised that the aim of the Indian artist is the suggestion of things unseen rather than a mere reproduction of things seen, the conventional and often unnatural forms of Indian religious figures become intelligible. If, for example, one sees in a figure with a multitude of arms a suggestion of infinite power, as the Indian image-maker intends that one should, the unnaturalness, from a physiological point of view, ceases to trouble one. For such things, as Mr. O. C. Ganguli has pointed out, "can hardly be represented in terms of a physically perfect and healthy body. They can only be symbolised in ideal types and by forms not strictly in accordance with known physiological laws but by forms which transcend the limits of the ordinary human body. The Indian artist was thus called upon to devise certain artistic conventions and a special system of anatomy suggestive of a higher and superior ethnical type for the purpose of intimating something beyond the form of things."*

Take another example. I have in my possession certain pictures of the Rajput school of painting, which possess a peculiar

* Foreword to "Some Notes on Indian Artistic Anatomy," by A. Tagore.

characteristic illustrating the paramount part played by suggestion in Indian art. They represent figures of men and women grouped in various attitudes in landscape gardens represented in strange perspective. The colouring is vivid, and the figures, though formal and, from a Western point of view, somewhat stiff and "unnatural," nevertheless give an impression of animation. I certainly derive a certain pleasure from looking at them. But I do not understand them; they do not convey to my mind a suggestion of anything beyond what actually appears upon the paper. For the Indian artist, however, they possess something which is hidden from me. The Hindu connoisseur on seeing any one of them will at once be reminded of a particular melody. For him the painting is visualised music. They provide a striking example of the intention of Indian art, namely, that of giving expression to the idea behind the appearance of things—of making manifest the abstract. The case is comparable to that of the analogy drawn by Schopenhauer of architecture to music. To all outward appearance there is no connexion between the two. The former exists in space without relation to time; the latter exists in time without relation to space. Yet the principles governing each, namely, symmetry and rhythm are seen upon reflection to be closely akin and to possess as their substratum a single idea. And it is this derivation from a common source that gives to Von Schlegel's description of architecture as "frozen music" its pleasing appropriateness.

Very well; there is, then, a clear distinction between the Art of India and that of Europe. Have the two arts clashed, and if so, what has been the result? Undoubtedly they have, and the result has been the same here as in the other fields of activity to which I have referred, namely, a spirit of revolt against the domination of the alien type. You find it in the writings of men of whom Dr. Ananda Coomaraswamy may be taken as typical. "There is no more depressing aspect of present day conditions than the universal decline of taste in India," he declares, "from the Raja whose palace, built by the London upholsterer or imitated from some European building, is furnished with vulgar superfluity and uncomfortable grandeur, to the peasant clothed in Manchester cottons of appalling hue and meaningless design." And his explanation of this state of affairs is coloured by the same spirit of revolt against alien domination as we find in the case of the politician and the educationalist. It is British domination that is primarily responsible. The beautiful Indian printed cottons of Madras disappeared before an avalanche of cheap machine-made goods from Manchester, ornamented with perfectly meaningless decoration such as rows of bicycles or pictures of bank notes. The introduction of an unsuitable architecture, and the influence of Government art schools are alike condemned; while the changes brought about in Indian taste and ideas by "a century of education entirely false in aims and method" are deplored.

And just as in the sphere of education this spirit of revolt has taken on a constructive form, so also has it done in the sphere of art. The modern school of Indian painting in Bengal is the offspring of this mental warfare. It was because the Government school of art failed to satisfy the spiritual thirst which parched their lips, that the brothers Tagore went forth from it to organise a school more in keeping with their own traditions. The significance of these developments was not lost upon the revolutionary politicians. "In Bengal," wrote one of them in 1917, "the national spirit is seeking to satisfy itself in art, and for the first time since the decline of the Moghuls a new school of national art is developing itself—the school of which Abanindra Nath Tagore is the founder and master."

I have said enough, perhaps, to show that there are solid grounds for my contention that in the clash of two ideals there is a real and potent source of unrest. In itself such unrest is healthy, and should command our sympathy and respect. It becomes a danger and a menace to India herself when it excites men to extremes causing a loss of all perspective. There is no wiser counsel that could be offered to Indians to-day than that given to them by one of the greatest of their own sages, Siddhartha Gautama, the Lord Buddha, two thousand five hundred years ago, when he urged them to avoid extremes and choose the middle way. "What do you think," he asked one who played upon a lute, "if the strings of your lute are too tightly strung, will the lute give out the proper tone and be fit to play? Or if the strings of your lute be strung too

slack, will the lute then give out the proper tone and be fit to play?'' And on receiving the answer: ''But how, if the strings of your lute be not strung too tight or too slack, if they have the proper degree of tension will the lute then give out the proper sound and be fit to play?" The lute player assented and received this exhortation: ''In the same way energy too much strained tends to excessive zeal, and energy too much relaxed tends to apathy. Therefore cultivate in yourself the mean.''

So to-day, is there not for Indians a golden mean between the adoption *in toto* of everything of the West on the one hand, and an equally rigorous rejection of all that the West has to offer on the other? If the undiscriminating and wholesale adoption of the manners and customs and modes of thought of the West by young Bengal during the 19th century was an evil, the undiscriminating and wholesale rejection of everything Western by Mr. Gandhi, Mr. Jitendra Lal Bannerji and others to-day, is every whit as much a misfortune. Is Sir Rabindra Nath Tagore any less an Indian than Mr. Gandhi because he was awarded the Nobel prize for literature? Is Sir Jagadis Bose any less an Indian than Mr. Jitendra Lal Bannerji because his achievements in science have been recognised by his admission to the fellowship of the Royal Society? On the contrary, have they not added to the stature of their country by their achievements? And would their achievements have been possible had they adopted the attitude of Mr. Gandhi and his followers?

Mr. Gandhi condemns railways. ''God set a limit,'' he says, ''to a man's locomotive ambition in the construction of his body.'' But did not God also equip man with the brain that discovered and then applied the locomotive power locked up in steam? I was present when Sir Jagadis Bose dedicated the institute which bears his name to the Indian Nation. In the course of his dedicatory address he said: ''It is forgotten that He who surrounded us with this ever evolving mystery of Creation, the ineffable wonder that lies hidden in the microcosm of the dust particle, enclosing within the intricacies of its atomic form all the mystery of the cosmos, has also implanted in us the desire to question and understand.'' Therein is to be seen the difference between the Indian lost in the mazes of an extravagant extremism and the Indian who has chosen the middle way. Sir Jagadis Bose stands a living prophet of the cause at whose altar I am myself an humble worshipper—that of the weaving of a synthesis of all that is highest and best in the thought and achievement of East and West. Does such contact between East and West as is embodied in the achievements of Sir Jagadis Bose in the realms of science uproot him from the intellectual soil of his own land? I trow not. The last time I saw Sir Jagadis was, once again, within the precincts of that building, which some years before I had heard him dedicate ''not merely a laboratory but a temple.'' He was standing beneath a picture which I have seen described as an ''allegoric masterpiece'' the picture of two figures, those of *Intellect* feeling the sharp edge of the sword with which he has to cleave his way through the dense darkness of ignorance, and his bride, *Imagination*, inspiring him with the music of her magic flute. It is the work of Nandalal Bose, one of the masters in that school of Indian painting, whose birth I have described. He was the scientist speaking of what had been accomplished in the Institute. He passed on to say something of his hopes. His face was lit up by the fire of enthusiasm, and expression and voice alike became those of the Seer—of the man with a message for mankind. There could be no shadow of doubt that in treading the pathway of the golden mean he had not merely retained but enhanced the value of his Indian parentage, or that in the empirical knowledge of the West he had found the complement of the intuitive knowledge of the East. But let him speak for himself. Telling the world long since of his discovery of the thinness of the partition between organic and inorganic matter, he said: ''It was when I perceived in them (the results of his experiments), one phase of a pervading unity that bears within it all things—the mote that quivers within ripples of light, the teeming life upon our earth, and the radiant sun that shines above us—it was then that I understood for the first time a little of that message proclaimed by my ancestors on the banks of the Ganges thirty centuries ago—

'' 'They who see but one in all the changing manifoldness of this universe,

unto them belongs eternal truth—unto none else; unto none else!' ''

* * * *

I prefaced my discourse with a prologue. Let me crown it with an epilogue. From the story of Vasishta the Brahman, and Visvamitra the king, I withheld the *dénouement*. I tell it now. Through the intervention of the gods the conflict between these warring parties was stayed; an honourable reconciliation took place. May this, my epilogue, prove prophetic of another and a greater reconciliation, to the benefit of India, of Great Britain, and of mankind.

DISCUSSION.

THE CHAIRMAN (Viscount Peel) said he was sure the audience felt much indebted to Lord Ronaldshay for his most eloquent and penetrating paper, on many aspects of the subject. Lord Ronaldshay had passed lightly over some of what, it was to be hoped, were the temporary causes of Indian unrest; he had said little of disturbances in Muslim feeling owing to troubles in Turkey, and of difficulties which had no doubt been set on foot by the war—all of which matters it might be hoped would disappear as the years went on—and had attempted to refer to one general cause of many of the phenomena with which the world was now familiar in India; and there was an intellectual satisfaction, even if there was no other, in tracing to one general cause phenomena so many-sided and various. He understood the purport of the paper largely to be as follows—That those Indians of whom Lord Ronaldshay spoke had standards of their own in art, in philosophy, and in the ways of life; that they loved those standards; that they disliked many of the standards set up by other countries (and to some extent those of the West), and that they were afraid that their standards might be overpowered by the influences of those foreign principles. That was really far wider than an Indian question. It raised really the whole problem of the reflex action—action and reaction of different civilisations, Eastern or Western, or whatever they might be, on other countries, and also problems of the deepest moment which were occupying us to-day. One of the difficulties was that those portions of our different civilisation which passed to other countries were rather the more volatile parts: the more solid were apt to remain behind. Looking at the difficulties from one aspect, it might be seen that they were part of a very general cause—the general feeling of revolt against the machinery of civilisation, which was not at all peculiar to this age or this time. It had found expression in the eighteenth century in that return to nature which had been given expression to by so many French writers. We were, in fact, all of us, at different times non-co-operators with the over-elaboration of life. We grew a little weary of those complexities which the intellect had inflicted on our experience, and we were very ready, in Bergsonian fashion, to bathe in the stream of life without the assistance of obscuring definitions. Western civilisation—and he did not limit it to British civilisation—was very many sided, and it might be that India and other portions of the East had seen too much of its purely machinery side—of its railways (though he was always being told there were not enough of those in India), of its roads, or its administration, of its statistics and figures and tabulation, and all the rather tiresome business which the organisation of great communities entailed, and of which many people saw a good deal too much as the days went by. His contention was that our civilisation was very far from being a material civilisation, and those who spoke of it as such, either did not understand it or were deliberately blind to many of its aspects. Did anybody who had read Shelley maintain that the British had no spiritual element in them? Could anybody who appreciated the vast range of our poets—he would not go back to Saxon times, but he would start with Spenser downwards—maintain that our civilisation was material? Could anybody familiar with the works of our philosophers and speculators—he meant in the thought sense—and with that profound love of adventure so deep in our natures, maintain that our civilisation had not a very ideal side to it?' He had been talking only the other day with the Emir Abdullah, the Emir of Transjordania, who said to him "Why is it that your men want to go up to the top of Mount Everest? What is there to see?" He had replied: "It is rather difficult to say, but I think it is part of that profound spirit of adventure in our race which finds out difficulties in order that it may conquer them and will not rest satisfied until it has explored the uttermost parts of the earth." Were not the pursuit of those Holy Grails ideal and not material? Perhaps we had been swept away in the last few years by those tremendous applications of science to life—but the last few years were a very small part in the history of Western civilisation. The object was to make life more tolerable, more humane, and to open up to everybody wider horizons. Our men of science pursued the love of knowledge for its own sake in order that they might appreciate and conquer the tremendous forces which surrounded them. Indeed, it might be said that science had idealised matter and made it spiritual. Just look at our whole political movement—that political movement of people who were supposed to be material. What were its two aims? One was to produce a feeling of goodwill among nations, so that there might be ample opportunity for human and cultivated life. The other, lying at the whole root of all the social system, was a better division

of this world's goods—not because of the value of the goods themselves but in order to secure leisure for improvement and culture, and that that culture might reach the many as well as the few. It seemed to him quite absurd to suppose that all that enriching of the garment of life which we owed to modern science could destroy the love of beauty and all thought of human culture and all those things which were greater far. It was said that it was more difficult for a rich man to attain heaven than for a camel to pass through the eye of a needle. That might be so, but even rich men frequently achieved that business nowadays. He was one of those who held that the effect which all this modern material civilisation, as it was called, had had, was enormously exaggerated. He believed that one could meditate just as well in a crowded railway train as sitting under a peepul tree with legs crossed. Indeed, the lamentations over the decay of modern life were really a sign of degeneracy in the people who gave utterance to them and not very much to be distinguished from those complaints over the decay in energy of the young men of our race which used to be made by elderly and dyspeptic persons before the Great War. What he claimed for our idealism was that it was a concrete idealism, based on and in close relation to, the facts of life, and therefore far more powerful and enduring than any idealism that might be based on mere speculation or on dreams alone. He had, of course, the greatest sympathy with many of those sides of Indian life to which Lord Ronaldshay had referred, and thought most of his listeners would regret deeply that the clash of creeds and other jealousies had prevented that close association between religious education and other forms of education, the divergence of which had too much to be lamented in our modern life in Western countries. With regard to the art side, Lord Ronaldshay had referred rather scornfully to Manchester goods. He (Lord Peel) happened to be the great grandson of a Manchester calico printer, and as he owed a good deal to such gentlemen he was not as contemptuous of them as the landed proprietor on his right! However, he had great hopes of Manchester himself, and with our growing sense of beauty he believed that those designs and colours which Lord Ronaldshay condemned would eventually come up even to the high ideal which Lord Ronaldshay advocated. Perhaps he might say just one word on the extent to which our political ideas had been absorbed in India. It would be seen that, though there might be rejections of many of our ideals and standards, there seemed to be a desire to appropriate many of our ideas. Indeed he was constantly meeting most distinguished Indian gentlemen who complained to him not that the dose was too weak but not nearly strong enough; that, to take an instance, dyarchy was a very poor substitute for full self-government. He did hope that his Indian friends would appreciate the splendid, as well as sordid sides of Western civilisation, and not reject what was good in it (and there was much that was good) merely because it was foreign and not indigenous. He trusted that they would examine it not in the spirit of propagandists, or even of politicians, he was going to say, but with that grave patience and philosophic temper which was noted by Lord Ronaldshay in their ancient sages. It might be, as Lord Ronaldshay had foreshadowed, that in the end, though the two ideals found indeed a great diversity and difference of expression, they were not so very far apart. As Plato said "The good is one."

Sir Valentine Chirol said he only claimed to speak on the ground of having had the advantage of visiting Bengal during Lord Ronaldshay's tenure of office, and he desired to bear witness to the excellent results which Lord Ronaldshay had achieved in reconciling the best Indian and the best European thought by practising what he had been teaching that afternoon. It was very rare to find Englishmen in India attempting even to understand the spirit that lay at the back of Indian art, and Indian music, which in many ways was so very remote from our own. He did not think anything could have helped more to secure for Lord Ronaldshay the popularity and regard of the people of Bengal (he was not speaking of Lord Ronaldshay's admirable work as Governor) than by making them feel that there were Englishmen who not only tried to understand, but succeeded in understanding those Indian aspects of life. He thought that that spirit would be shown more and more by those Englishmen who went out in any capacity, whether as Governors like Lord Ronaldshay, or as humble travellers like himself, who would try to understand, without necessarily sharing or approving, what was the point of view of the Indian mind. There were plenty of Englishmen who, like their Chairman, Lord Peel, would dwell upon the merits of our civilisation. One could do so with great effect; but it was important, and more difficult, for Englishmen to appreciate and to understand the value of Indian civilisation, an ancient civilisation older than our own, and one which swayed as large a proportion of the population of the world as did ours. He thought it was very unfortunate—to take one instance only—that a great statesman who was chiefly responsible for the introduction of Western education into India—Lord Macaulay—should have coupled as he did his praise of Western education and his determination to have it introduced into India with the most violent, scornful and almost vitriolic attack upon the value of Sanskrit and all the literature and beliefs that stood behind Sanskrit. He (Sir Valentine Chirol) thought we had not recovered from that yet. There was one other difficulty, namely, that owing to the peculiar position of the Government and the quite

intelligible desire to maintain neutrality between the different creeds of India, Government had to abstain from stressing the moral side of Western education. The intellectual side was a very high one, but the moral side of Western education, he believed, was even higher than the intellectual side, and that side had been terribly neglected, owing to an almost excessively punctilious desire to remain neutral. In one respect Lord Ronaldshay did not desire us to remain neutral, and he quite agreed with him. Lord Ronaldshay wanted us to try to understand and to act upon an appreciation of what was best on the Indian side as well as on our own, and he thought his lordship had rendered a very great service by the paper he had written.

Sir Francis Younghusband, K.C.S.I., K.C.I.E., thought it was a matter on which the Fellows of the Royal Society of Arts ought to congratulate themselves with extreme heartiness that a successful Governor (so successful that the Royal Geographical Society had had no hesitation in nominating him for election to its Presidency) should have taken the pains to attend there and state what were the root causes of the estrangement between ourselves and the Indians. Lord Ronaldshay had gone right down to the fundamental problems, which were not so often spoken of and dwelt upon and explained as they should be. He was not quite clear whether Lord Ronaldshay desired to strike the golden mean and follow the middle way, or whether he desired to engage in the process of weaving a synthesis of all that was highest and best in the two civilisations, Eastern and Western. For himself, he was not a believer in the golden mean. He maintained that the highest good would be attained by extracting out of each civilisation all that was best in it. As an illustration he might mention that some months ago he had listened to an exceedingly eloquent and well delivered lecture by Mr. Sastri upon Gandhi's life and ideas. The remarkable thing was that Mr. Sastri had kept pressing upon his audience the fact that Gandhi was too spiritual and that he must have something practical down at bottom. That afternoon Lord Peel had said how very spiritual Western civilisation was, and one got from the pressing together of the two, the essential and best points of each. To a certain extent he agreed with Lord Peel when he said that British civilisation was very much more spiritual than the Indians believed, but nobody could say honestly that it was anything like spiritual enough—and that was really the main point. It was quite understandable that Indians should get the impression that we were not a spiritually-minded people. If one took up any daily newspaper one would see columns and columns devoted to business, politics and sport, but only one column a week perhaps was devoted to religion. The same thing applied all the way through the lives of Western people. Outwardly, at any rate, extraordinarily little attention was paid to religion in comparison with what the Indians were expected to do. Therefore, he quite agreed with Lord Ronaldshay that we must understand the Indian point of view, but he would like to add to that, that we should understand ourselves, and the essential need there was of more spirituality in ourselves.

At this point Lord Peel had to vacate the Chair on account of public business, and his place was taken by Sir Charles S. Bayley, G.C.I.E., K.C.S.I., Chairman of the Indian Section Committee.

Mr. W. R. Gourlay, C.S.I., C.I.E., I.C.S., said the paper was most interesting and helpful. He had served in India for twenty-five years and had had unique opportunities of coming in contact with almost all Indian political opinion in Bengal. He had had, and still had, friends, even among some who held the most extreme views. In his conversations and in his friendship with those men he had been constantly coming up against difficulties which he had not understood, and which he was afraid he had let pass because he had not understood, and he had not probed deep enough to find out the reasons for them. He had found Lord Ronaldshay's address most helpful, as it would be to anyone who was an officer in India. He had had the privilege of working in close association with Lord Ronaldshay during the whole of his Governorship, and could testify to the fact that there was no Governor under whom officers would better like to work. They had the greatest admiration for him. First of all there was in Lord Ronaldshay a desire to see the other man's point of view and a respect for the other man's point of view—whether that man was an Indian or anybody else. Then Lord Ronaldshay had the courage to face the other man's point of view, and when he had come to his own conclusions, to state them for the benefit of other people. From the first day that Lord Ronaldshay had gone to India he had set himself to find out what was behind things. He did not merely sit in an office chair and dispose of large quantities of files, but went personally and with great industry into everything to find out all that was to be found out. In addition Lord Ronaldshay had the power of leading his subordinates to think as he himself did and to see the various points of view as he himself did. The work Lord Ronaldshay had done in the last five years in Bengal would made a great difference in the future to the whole of the Indian continent.

Mr. Alan F. Fremantle, I.C.S., said that it was with great diffidence that he took part in the discussion in the presence of his official superiors, but he was emboldened to do so by the feeling that perhaps some of those present would like to hear the point of view of an Indian

Civil Servant who had recently been bearing the burden and heat of the day. He would like to state what he believed to be the view of the ordinary man serving in India, and the ordinary resident of India, as to the causes of Indian unrest. India was a very hot country with an execrable climate, and the psychological result of that was that a disproportionate amount of importance was attached to action and an undue amount of importance to words, because activity was very difficult and occasionally impossible. A comparatively small section compared with the whole community of India—but still a fairly large number of Indians—had received English education, and having acquired a power of language which made them equal in writing articles and making speeches to Englishmen, and believing that language was the vehicle of thought and thought was a measure of the universe, were over hasty, as Englishmen thought, in grasping at power. That sort of thing had started forty or fifty years ago, long before anything was heard about the conflict of ideals between the West and the East. At that time the only claim which the educated Indians made was that they had a right to govern their fellow countrymen, because they were exactly like English people except for the mere difference of colour and the place where they were born. But when their claims were not being fully listened to, they were up against a great difficulty. They were then only a very small section of the community, and the community as a whole had been quite happy under the existing rule. They had been up against the difficulty of moving what was generally known for the purpose of convenience as the dumb millions. They had found out very soon, what most people in Europe had found out, that the dumb millions had no brains, but to make up for that they had pretty large stomachs and pretty large hearts. There were two ways of affecting the dumb millions. One was to appeal to their stomachs. That was called the economic argument. They had tried that, without great success. The other was to appeal to their hearts. That was generally done by means of religion. Lord Ronaldshay had very eloquently described the Bengali attempt at an appeal to religion. It had not been a wholly successful one. As his lordship had pointed out, the attempt had failed, and by about 1917 the agitation in Bengal had subsided. Then there came the man, to whom all the political agitators who had ever existed in Bengal were as children, namely, Gandhi. He showed a better way of conducting an agitation. With extraordinary skill he had been able to get himself accepted as a saint with superhuman powers, whose miracles were the talk of every bazaar. From that position of eminence he proceeded to denounce the Government of India as materialistic and godless and profane. Everybody knew—none better than Gandhi himself—that the picture he drew of the Government of India—its upsetting the religious ideals of India, destroying Indian art and destroying everything beautiful—was perfectly absurd. In fact, Gandhi himself in one of his earlier speeches said that he liked the Government of India because the British Government was a government which governed least. He knew that the British Government was not an interfering Government. He knew, so far as material ideas had invaded India, that that was a trouble from which everybody suffered. We ourselves suffered from the invasion of industrialism just as much as they did in India. He (Mr. Fremantle) believed there was no reality in the claim that the British Government was antagonistic to Indian culture. So far as it had happened, it had happened owing to the world process, which could not be helped. He presumed that something of the same sort went on even in China, which was not under European Government at all. He refused—and he spoke for Englishmen serving in India—to stand in a white sheet with regard to the matter. He refused to admit that those who had been brought up at English public schools and universities had not a respect for everything that was old and national and peculiar, and he refused to admit that those who had drunk deep of the knowledge of the glory that was Greece and of the grandeur that was Rome grudged the Hindus the comfort they derived from the Sakuntala and the Bhagavad Gita.

Mr. S. B. Gadgil, F.R.C.S., said it was rather difficult to make an extempore speech after the well-considered and thought-out address of Lord Ronaldshay, in which his lordship had tried to analyse the minds of the Indian people and to account for their actions and behaviour at the present time. It must be rather heart-breaking for a Governor, and for Indian Civil Servants, who were doing their very best to make the people of India happy and contented under a rule which was very much better than they used to have, to see the country being disturbed by means of the non-co-operation movement. He could assure his hearers, from news that he had received from India, that the non-co-operation movement was a very temporary thing, and that the people in India had complete confidence that the British people really meant what they said—that they desired to bring the Indian people up to the level of all the modern nations. There was no doubt that in their heart of hearts all Indians were thankful to the British for everything they had introduced into India. Even the Hindus were thankful for the Christian religion, because it had made them analyse their own religion and see what was best in it. The people of India would always be grateful to the British and ready to co-operate with them so long as they were convinced that the British people were determined to bring Indians to their proper status in the Commonwealth of Nations forming the British Empire.

LORD RONALDSHAY, in reply, said he had been very conscious when he selected the subject for his paper that he would run a grave danger of laying himself open to misunderstanding,—the misunderstanding, that was to say, that he himself accepted the views which he had quoted from the mouths of others. With regard to what Lord Peel had said about Manchester cotton, he himself was a great admirer of many of the products of the Manchester looms, and what he had said about them in the paper was not his own view but a quotation of a statement of an Oriental writer. It was quite true, as that gentleman had said, that the designs on Manchester cotton which was sent out to India were not really always quite suitable to the country. It was not a question of Manchester goods being bad on their merits, but whether they were chosen with a due consideration of their appropriateness for the market to which they were being dispatched. Dr. Coomaraswamy mentioned a case of yards and yards of Manchester cotton having been sent to the people of Madras bearing designs of bicycles and banknotes, which conveyed nothing to the people who were expected to buy the goods. With reference to the golden mean referred to by Sir Francis Younghusband, he need hardly say that he repudiated with all the emphasis he could command the views expressed by Mr. Gandhi as to the material character of Western civilisation. He was as proud of the achievements of Western civilisation as any Westerner could be. What he wanted to urge upon Indians when he suggested that the best advice they could accept at the present day was that of following the middle way, was merely that, while they should not do what the young Bengalis of last century did, namely reject *in toto* their own past and accept *in toto* without discrimination, everything Western, they should not reject *in toto* everything Western and assume that everything in their own civilisation was supremely good. What they wanted to do, surely, was to take the best of both civilisations; in other words, to do as Sir Jagadis Bose had done. Sir Jagadis Bose had been singularly successful in combining the scientific knowledge of the West with the imaginative and intuitive knowledge which was certainly a marked characteristic of some of the races of the East. If those two qualities could, with discrimination, be combined, it seemed to him to be quite certain that the result would be admirable and wholly satisfactory. He had tried to place before the Society that afternoon what had struck him during the past five years as being the standpoint of an appreciable section of the people of Bengal. He did not say it was the standpoint of everyone, naturally, because Bengal was a large country with forty-five million people, and in no country in the world, least of all Great Britain, as anybody who had taken part in a General Election would testify, did everybody think exactly like. He had tried merely to place before an English audience the point of view of an appreciable section of the Indian people upon matters which appeared to him to be of fundamental importance.

H.H. THE MAHARAJ RANA OF JHALAWAR, K.C.S.I., said it gave him great pleasure to offer his thanks to Lord Ronaldshay for his most illuminating address. It might be a surprise to some people to learn that the present occasion was the first on which he had seen Lord Ronaldshay in person, but he had had the good fortune of knowing him through correspondence, and he had always held his lordship in the greatest respect and regard. He (the Maharaj Rana) came into contact with a number of Bengali gentlemen and other Indians and they all admired Lord Ronaldshay's administration in Bengal. Undoubtedly, when two civilisations met they brought about some sort of friction, but he was quite certain that if the English people took the same view of the matter as Indians took, namely, give and take, everything would be all right, and India would again soon become a place of rest and happiness. His Highness concluded by proposing a vote of thanks to Lord Ronaldshay and the Chairman.

SIR CHARLES BAYLEY seconded the vote of thanks to Lord Ronaldshay for his exceedingly informing, interesting, and illuminating address, and also to Lord Peel for having given up his valuable time in order to take the Chair that afternoon, and, it might be added, for the remarks which he had made in defence of the idealism of the West. Another reason why Lord Ronaldshay should be thanked was that his address had led others who had made a lifelong study of the subject to speak from their different points of view. He thought all must agree that where a strong civilisation like the Western had broken in on the old civilisation of the East as ours had done, action and reaction were sure to occur. There were bound to be swings of the pendulum. They had been told how it had swung strongly Westward at first; now it seemed to be swinging strongly Eastward, but he thought there would be further swings, and that each swing would grow less and less until it was permissible to hope that in the end the pendulum might reach a state of equilibrium, when both sides would have absorbed what was best in each other.

The motion was carried unanimously and the meeting terminated.

OBITUARY.

ALEXANDER ROSS.—Mr. Alexander Ross, who died suddenly at Hampstead on the 3rd inst., had been a Fellow of the Royal Society of Arts since 1898. Born in 1845, he was educated at Aberdeen and Owen's College, Manchester.

From 1862 to 1871 he served as a pupil with the Great North of Scotland Railway, after which he was appointed an assistant on the Northern Division of the London and North Western Railway, and in 1875, District Engineer to this Company at Liverpool. In 1884, he became Assistant Engineer to the Lancashire and Yorkshire Railway, and in 1890 Chief Engineer of the Manchester, Sheffield and Lincolnshire, now the Great Central Railway. In 1897 he was appointed Chief Engineer to the Great Northern Railway, a post which he held until 1911, when he started practice as a consulting engineer.

Mr. Ross was President of the Institution of Civil Engineers in 1915-16, and he was a member of the Metropolitan Munitions Committee. He was interested in a scheme for an outer circle railway linking up the railways running north of London, and also in providing a passenger subway from the House of Commons to Whitehall Gardens.

Sir Joseph Walton, Bt., D.L.—Sir Joseph Walton, ex-M.P., merchant and coalowner, died at Bournemouth on Friday, February 8th, in his seventy-fourth year. The son of a Northern coal owner, he was born at Bollihope, County Durham, and at an early age, in fact when quite a youth, started business on his own account at Middlesborough. From 1897 to 1918 he sat in the House of Commons as member for the Barnsley division of the West Riding and from the latter year to the recent General Election for the borough of Barnsley. A Liberal Imperialist he was an active politician and his public services were recognised by his being created a Baronet in 1910. He joined the Royal Society of Arts as long ago as 1894 and took much interest in its work, especially in connexion with Imperial affairs. He gave the Society two useful papers, one in 1894 on "Indian Railway Extension and its Relation to the Trade of India and of the United Kingdom" and the other in 1901 on "The China Crisis—its Causes and its Solution." He also took part in discussions at numerous meetings of the Indian and Dominions Sections.

NOTES ON BOOKS.

Molybdenum Ores. By R. H. Rastall. London: John Murray. 5s. *net.*

Booklets on various aspects of industrial geography, issued under the auspices of the Imperial Institute, have proved of value in so many ways, that we are pleased to receive an addition to the series which treats of mineral resources with special reference to the British Empire; a series of which the earlier issues include Manganese Ores, by Curtis, Tin Ores, by Davies, Tungsten Ores, by Rastall and Wilcockson, Coal by Ronaldson, Platinum Metals by Lamb, Lead Ores by Hale, Chromium Ore by Rumbold, Petroleum, Silver Ores, and Oil Shales by Cronshaw, also Potash by Johnstone.

Molybdenum, which is well and fully treated of in the 86 pages of the work now under notice, was first foreshadowed as a distinct metal by Scheele, in 1778, but the isolation of the metal was imperfectly realised somewhat over half-a-century ago by Debray, who found it extremely hard and quite unworkable.

Now it is obtained in a decarbonised state as a comparatively soft silver-white metal which is malleable and ductile, but very difficult to fuse, so ranging with or beyond platinum in this respect. Its main use now is for alloying with iron or steel to secure special qualities.

The small handbook before us, apart from the good general account of Molybdenum and its industrial uses, gives a world map of sources and a comprehensive industrial bibliography.

Dr. Rastall's work may thus be regarded as an essential item in the library of an iron and steel manufacturer.

Synthetic Colouring Matters. Dyestuffs Derived from Pyridine, Quinoline, Acridine and Xanthine. By J. T. Hewitt, F.R.S. London: Longmans, Green and Co. 14s. *net.*

A work on synthetic colouring matters has a special value for the student when the author is a laboratory worker of eminence, whose detailed knowledge of his subject is largely first-hand. Not only has the work before us this advantage, but Dr. Hewitt has the power of expressing a full and exact meaning in few words; and his habit of giving abundant references to original sources also conduces towards making the XII + 406 pages virtually equivalent to what many would expect to obtain in a much larger work.

The usefully practical mind of Dr. Hewitt is well reflected in the numerous details as to proportional quantities and times required for productive operations, and his effective conciseness in this respect is well illustrated on page 190, where, in a dozen lines, we have two quantitative instructions for preparing a phenonaphthacridine, and the need of lengthy theoretical explanations is minimised by the extensive use of constitutional formulæ and by cleverly contrived tabulations in relation to constitution and physical properties: both characteristics being well illustrated by opening the book so as to display pages 204 and 205. It will be noted that much space is saved on page 205 by printing the melting points of six nitration products adjacent to the constitutional formulæ.

One who is accustomed to books can see almost at a first glance, that the main sheets are not British printing: minor details of typographic usage giving the indication, while a glance at the final page shows a prominen ly displayed

imprint of a well-known firm in Saxony. The reason of this is probably to be found in the great difficulty (or perhaps impossibility) of finding a British printing firm willing to undertake a multitude of constitutional formulæ like those in Dr. Hewitt's book. Indeed, it is doubtful whether any British printing firm has the type-sorts for bringing the expression on page 293 within the limits of the page or who would be willing to encroach into the whites as on page 285.

Even if practicable to produce the printed sheets in Great Britain the cost would probably have made the work almost unsaleable, whereas now we have a much-wanted text book at a low price; a work which, with the half-dozen or so that are to follow, may do much towards restoring to Great Britain that pre-eminence in the manufacture of synthetic colours which was hers in the sixties and early seventies.

PHOTOGRAPHIC COLOUR-SENSITISING DYES.

It is interesting to note that the work before us covers the nature and manufacture of all the really important photographic colour sensitising dyes, that is, those of the cyanine class. This is done with a completeness and lucidity characteristic of Dr. Hewitt, and those who wish for a treatise on the colour sensitising cyanines, which is quite unparalleled by anything yet published, whether British or foreign, will find what they require here.

As it stands, Hewitt's "Synthetic Colouring Matters" is a credit to all concerned, and an addition to our national resources, as it may be a turning point in the development of a branch of manufacture which has drifted to a low ebb in Great Britain.

A NEW SOUTH AFRICAN MOTOR FUEL.

According to a report by the United States Trade Commissioner at Johannesburg, a new petrol substitute has been invented by a resident of Edenburg, in the Orange Free State. The formula for this new product is a secret, but it is made from the juice of the prickly pear mixed with other chemicals. According to press reports, the spirit has been severely tested on various makes of cars and is highly recommended, being non-corrosive, odourless and equal to or better than petrol in power and flexibility, a mileage of 22.4 being obtained in a six-cylinder car. It has also been tried out by farmers for both tractors and cars, and it is stated that no difference could be detected between running on petrol and on the new fuel. No special carburetter adjustments are necessary.

A company has been formed with a capital of £100,000 to exploit the invention, and a plant has been obtained with a capacity of 2,000,000 gallons, which is estimated as one-sixth of South Africa's consumption. The cost of production is given as ninepence per gallon, and it is reckoned that the retail price will be about half that of petrol. It is claimed that all of the ingredients are "obtainable in inexhaustible supplies in South Africa." The prickly pear grows wild in many parts of the country and has become, in fact, a pest, devastating thousands of acres of farm land.

The merits of this new fuel, adds the Trade Commissioner, will have to be fully demonstrated before too much credence can be given to its competitive qualities.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, FEBRUARY 19 .. British Architects, Royal Institute of, 9 Conduit Street, W., 8 p.m. Mr. H. V. Lanchester, "Architecture and Architects in India."

Textile Institute, Huddersfield, 7.30 p.m. (Joint meeting with the Huddersfield Textile Society). Mr. W. Baines, "An Enquiry into the Comparative Efficiency of different sizes of Carding Machines used in making lower grade Woollens."

Geographical Society, Lowther Lodge, Kensington Gore, S.W., 5 p.m. Dr. R. L. Sherlock, "The Influence of Man as an Agent in Geographical Change."

Bankers, Institute of, Talbot Lane School, Wilfrid Street, Rotherham, 7.30 p.m. Mr. A. Sells, "National Finance: Is a Capital Levy desirable and practical?"

Faraday Society, at the Chemical Society, Burlington House, Piccadilly, W., 8 p.m. (1). Professor A. W. Porter, and Mr. J. J. Hedges, "The Law of Distribution of Particles in Colloidal Suspensions with Special Reference to Perrin's Investigations." Part II. (2). Mr. D. B. McLeod. (a). "On a Relation between the Viscosity of a Liquid and its Co-efficient of Expansion." (b), "On the Viscosity af Liquid Mixtures showing Maxima." (c), "On a Relation between Surface Tension & Density." (3) Mr. M. Cook, "Crystal Growth in Cadmium." (4). Mr. F. H. Jeffery, "Electrolysis with an Aluminium Anode the Anolyte being (1), Solutions of Sodium Nitrite (2), Solutions of Potassium Oxalite." (5). Mr. S. D. Muzaffer, "Electric Potential of Antimony-Lead-Alloys."

University of London, University College, Gower Street, W.C., 5 p.m. Mr. D. W. Cutler, "Protozoa of the Soil." At King's College, Strand, W.C., 5.30 p.m. Dr. W. Brown, "Psychology and Psychotherapy." (Lecture I.) 5.30, Rev. C. F. Rogers, "Ecclesiastical Music." (Lecture III.) 5.30 p.m., Prof. R. Dyboski, "Poland." (Lecture V.)

TUESDAY, FEBRUARY 20 .. Statistical Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.15 p.m. Mr. J. Hilton, "Statistics of Unemployment derived from the Working of the Unemployment Act."

Illuminating Engineering Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 8 p.m. Messrs. W. J. Jones and E. A. Marx, Junr., "The Projection of Light."

Transport, Institute of, at the Institution of Electrical Engineers, Savoy Street, Victoria Embankment, W.C., 5.30 p.m. Messrs. F. Bushrod and J. F. S. Tyler, "Modernisation of Passenger Railway Stations."

Sociological Society, at the Royal Society, Burlington House, W., 8.15 p.m. Prof. J. A. Thomson, "Biological Contributions to Sociology."

Oriental Studies, School of, London Institution, Finsbury Circus, E.C., 5 p.m. Dr. P. G. Bailey, "The Sansis or Thieves of India; their Language, History and Customs."

Civil Engineers, Institution of, Great George Street, S.W., 6 p.m.

Anthropological Institute, 50, Great Russell Street, W.C., 8.15 p.m. Mr. P. E. Newberry, "The Beb Sed Festival of Ancient Egypt."

Photographic Society, 35, Russell Square, W.C., 7 p.m. Mr. A. S. Newman, "On Static Trouble with the Kinematograph and Means for its Elimination."

University of London, University College, Gower Street, W.C., 5.30 p.m. Mr. J. H. Helweg, "Contemporary Danish Literature." (Lecture III.) 5.30 p.m. Mr. N. H. Baynes, "The Roman Empire in the IV. Century." (Lecture III.) At King's College, Strand, W.C., 5.30 p.m. Professor H. W. Carr, "Physical Causality and Modern Science." (Lecture I.) 5.30 p.m., Sir Bernard Pares, "Contemporary Russia from 1861." (Lecture V.), 5.30 p.m., Mr. A. J. Toynbee, "The Expansion of Europe Overland; the Route of the Steppes." (Lecture I.) 5.15 p.m., Dr. J. H. Orton, "The Bionomics of Marine Animals." (Lecture I.) At the London School of Economics, Houghton Street, Aldwych, W.C., 5 p.m. Mrs. S. P. Vivian, "Statistics before, during and after the War." (Lecture I.) "Population."

Production Engineers, Institution of (Coventry Branch), 7.30 p.m. Mr. J. D. Scaife, "Ball and Roller Bearing Manufacture."

WEDNESDAY, FEBRUARY 21 .. Royal Institution, Albemarle Street, W., 3 p.m. Dr. A. C. Pearson, "Greek Civilisation and To-Day." (Lecture II.)

Microscopical Society, 20, Hanover Square, W., 8 p.m. Prof. Sir William M. Bayliss, "Microscopical Staining and Colloids." Mr. A. Mallock, "Test Plates for Microscopes, and Microscopic Definition."

United Service Institution, Whitehall, S.W., 3 p.m. Field-Marshall Sir W. R. Robertson, "Policy and Strategy."

Meteorological Society, 49, Cromwell Road, S.W., 7.30 p.m.

British Academy, at the Royal Society, Burlington House, Piccadilly, W., 5 p.m. (Raleigh Lecture). Rear-Admiral H. W. Richmond, "National Policy and Naval Strength, XVIth to XXth Century."

Public Health, Royal Institute of, 37, Russell Square, W.C., 4 p.m. Brevet-Colonel L. W. Harrison, "The Organisation and Administration of Venereal Disease Schemes."

Industrial League and Council, Caxton Hall, Westminster, S.W., 7.30 p.m. Mr. W. A. Appleton, "Economics of War and Peace."

University of London, University College, Gower Street, W.C., 5.15 p.m. Prof. M. Walker, "The Control of the Speed and Power Factor of Induction Motors." (Lecture I.) 5 p.m., Dr. B. M. Bristol, "Soil Algæ." 5.30 p.m., Mr. J. C. Gröndahl, "The Work of Wergeland." (Lecture III.) 5 p.m., Mr. P. Leon, "The Theory of Beauty." (Lecture II.) At King's College, Strand, W.C., 5.30 p.m. Prof. F. Soddy, "A Physico-Chemical Theory of the Instability of Western Civilisation."

THURSDAY, FEBRUARY 22 .. African Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5 p.m. Mr. C. W. Hobley, "Some Native Problems in Eastern Africa."

Dyers and Colourists, Society of, The University, Leeds, 7 p.m. Mr. D. T. McLellan, "Some Observations on the Preparing and Dyeing of Woollen Pieces."

Royal Society, Burlington House, Piccadilly, W., 4.30 p.m.

Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.

London County Council, Geffrye Museum, Kingsland Road, E., 7 p.m. Mr. O. Brackett, "Thomas Chippendale."

Camera Club, 17, John Street, Adelphi, W.C., 8.15 p.m. Mr. E. R. Ashton, "Picturesque India."

Royal Institution, Albemarle Street, W., 3 p.m. Mr. B. M. Jones, "Recent Experiments in Aerial Surveying." (Lecture II.)

University of London, University College, Gower Street, W.C. 5.30 p.m., Mr. J. Björkhagen, "Swedish Literature in the XVIII. Century." (Lecture IV.) 5.30 p.m., Mr. G. A. Sutherland, "The Acoustics of the Auditorium." (Lecture III.) 5.15 p.m., Mr. J. E. G. de Montmorency, "Distribution of Customary Law in England and France." At King's College, Strand, W.C. Prof. W. Barthold, "The Nomads of Central Asia. (Lecture VI.) 5.15 p.m., Dr. J. H. Orton, "The Bionomics of Marine Animals." (Lecture II.) 5.30 p.m., Mr. L. Wharton, "Some Poetry of Mickiewicz." At the London Hospital, Mile End, E., 4.30 p.m. Mr. W. A. M. Smart, "The Mathematical Basis of Physiological Problems." (Lecture VI.)

Auctioneers and Estate Agents Institute, 34, Russell Square, W.C., 7.30 p.m. Mr. J. S. Kirkwood, "Aerial Surveys and Topography demonstrated by Photographic Examples."

Central Asian Society, at the Royal United Service Institution, Whitehall, S.W., 5 p.m.

Structural Engineers, Institution of, 296, Vauxhall Bridge-road, S.W., 7.30 p.m. Mr. E. Godfrey, "Shear Resistance."

Chemical Society, at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W., 8 p.m. Principal J. C. Irvine, "Some Constitutional Problems of Carbo-Hydrate Chemistry."

British Architects, Royal Institute of, 9, Conduit Street, W., 5 p.m. Sir Ryland Adkins, "Architecture and the Countryside in Layman's Questions."

FRIDAY, FEBRUARY 23 .. Royal Institution, Albemarle Street, W., 9 p.m. Prof. A. S. Eddington, "The Interior of a Star."

Production Engineers, Institution of, at the Engineer's Club, Coventry Street, W., 7.30 p.m. Mr. T. F. Hardyman, "Machine Moulding Methods."

Photographic Society, 35, Russell Square, W.C., 8 p.m. Mr. A. Pereira, "Off the Track in Africa."

Physical Society, Imperial College of Science, South Kensington, S.W., 5 p.m.

Auctioneers and Estate Agent's Institute 34, Russell Square, W.C., 11 a.m. Conference of Agricultural Members. 2.30 p.m., Mr. C. B. Marshall, "The Working of the Agricultural Act, 1920."

Engineers, Junior Institution of, 89, Victoria Street S.W., 7.30 p.m. Mr. A. J. Tracey "Characteristics, Operation and Maintenance of Underground Cables."

University of London, University College, Gower Street, W.C., 5 p.m. Prof. O. Elton "English Literature: the Poetry of Manners." At King's College, Strand, W.C., 5.15 p.m. Dr. J. H. Orton, "The Bionomics of Marine Animals." (Lecture III.) 5.30 p.m. Dr. R. W. Seton-Watson, "Serbia and the Jugo-Slav Movement." (Lecture VI.)

SATURDAY, FEBRUARY 24 .. Royal Institution, Albemarle Street W., 3 p.m. Sir Ernest Rutherford "Atomic Projectiles and their Properties." (Lecture II.)

London County Council, at the Horniman Museum, Forest Hill S.E. 3.30 p.m. Mr. S. H. Warren, "The Interplay of Land and Sea."

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FRIDAY, FEBRUARY 23, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W C (2

NOTICES.

NEXT WEEK

WEDNESDAY, FEBRUARY 28th, at 8 p.m. (Ordinary Meeting.) PROFESSOR W. E. S. TURNER, D.Sc., Head of the Department of Glass Technology, University of Sheffield, "Heat Resisting Glasses." THE HON. SIR CHARLES A. PARSONS, K.C.B., LL.D., D.Sc., F.R.S., will preside.

Further particulars of the Society's meetings will be found at the end of this number.

RE-OPENING OF THE LIBRARY.

The Library, which has been entirely renovated and re-furnished, is now open to Fellows daily from 10 a.m. to 6 p.m. (Saturdays 10 a.m. to 1 p.m.).

Fellows can obtain tea between 4 and 6 p.m. at moderate prices.

ELEVENTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 14th, 1923; MR. H. J. C. JOHNSTON, President of the Institution of Clay Workers, in the Chair.

The following candidates were proposed for election as Fellows of the Society:-

Ardeshir, Hormasji, Bombay, India.
Chatterjee, Girija Bhusan, Saduhati, India.
Hamid, Khan Bahadur Diwan Abdul, O.B.E., M.L.C., Kapurthala, India.
Johnson, Alfred Sidney, M.A., Ph.D., Chicago, U.S.A.
Ryan, Paul, Tankerton, Kent.
Walsh, Charles Peregrine, Crondall, Hants.

The following candidates were duly elected Fellows of the Society:—

Angell, Colonel Frederick John, C.B.E., Bedford.
Angus, J. A., Rangoon, Burma.
Armstrong, Thomas Francis, Kathiawar, India.
Crosby, Lieut.-Colonel Walter Wilson, D.Sc., M.Am.Soc.C.E., Grand Canyon, Arizona, U.S.A.
Kinsman, Arthur Daniel, Ipswich, Mass., U.S.A.
Leaf, E. L., London.
Lloyd-Dodd, A. E., B.Com.Sc., Lisburn, Ireland.
McLaughlin, Robert Samuel, Ontario, Canada.
Singh, S. Inder, Cawnpore, India.
Townsend, Sydney Robert Maurice, London.

INDIAN SECTION.

FRIDAY, FEBRUARY 16th, 1923; SIR EDWARD A. GAIT, K.C.S.I., C.I.E., Ph.D., Member of the Council of India, in the Chair.

A paper on "The Census of India of 1921," by MR. J. T. Marten, M.A., I.C.S., Census Commissioner for India, was read by MR. L. MIDDLETON, I.C.S., Provincial Census Superintendent, Punjab.

The paper and discussion will be published in a subsequent number of the *Journal*.

The Council have appointed Mr. H. A. F. Lindsay, C.B.E., I.C.S. (Indian Trade Commissioner), a member of the Indian Section Committee in the place of Mr. F. Noyce, C.B.E., I.C.S., who has returned to duty in India.

CANTOR LECTURE.

On Monday evening, February 19th, Dr. Henry P. STEVENS, M.A., F.I.C., delivered the third and final lecture of his course on "The Vulcanisation of Rubber."

On the motion of the Chairman, MR. WALTER C. HANCOCK, a vote of thanks was accorded to Dr. Stevens for his interesting course.

The lectures will be published in the *Journal* during the summer recess.

BINDING COVERS FOR JOURNALS.

For the convenience of Fellows wishing to bind their annual volumes of the *Journal*, cloth covers can be supplied, post free, for 2s. each, on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.

SEVENTH ORDINARY MEETING.

WEDNESDAY, JANUARY 17TH, 1923.

DR. T. M. LEGGE, C.B.E., H.M. Medical Inspector of Factories, in the Chair.

The following paper was read:—

"HYGIENIC METHODS OF PAINTING: THE DAMP RUBBING-DOWN PROCESS."

By C. A. KLEIN.

In a paper read before this Society by Professor H. E. Armstrong, F.R.S., and myself, on July 14th, 1921(1), we endeavoured to present a comprehensive survey of the scientific information then available in respect to the industrial risks of the painting craft. The whole of the known dangers were discussed, and the importance of dust in relation to lead poisoning was emphasised. It was shown that of the operations involved in the practice of painting, that of dry rubbing down was the most serious source of dust production, and, further, it was pointed out that the danger of lead poisoning lies almost entirely in the inhalation of dust.

In view of the fact that there is little published information as to quantitative and qualitative investigations of the process of dry rubbing down, it was decided to make a detailed study of this operation, and to ensure results of practical value, arrangements were made to investigate the operations of working painters following their regular work. These investigations were made partly in Manchester, London and Brimsdown (Middlesex), so that the variations due to three different sets of workers were obtained.

The figures obtained clearly show that in work of this description there are a number of uncontrollable factors which do not permit of absolute agreement in duplicate experiments. Amongst these factors must be noted such variations as the extent of muscular effort exerted by an individual painter, the height of the worker in relation to his work, and the distance at which workers stand from their work. These are uncontrollable factors.

Variations due to differences in the character of the surface, *i.e.*, glossy or flat, smooth or irregular, age of paint film and character and size of abrasive material, are, to an extent, controllable, but where the human factor alone is involved, control is not only difficult, but undesirable. It was found that even in the case of the same worker engaged in precisely similar work, using the same materials, on two different days, there was not absolute agreement in tests of the quality and quantity of dust produced per unit area or time.

In view of these facts, I am convinced that results obtained in investigations of this description can be regarded only as typical, and not of necessity absolute; they do, however, provide reliable data from which fundamental conclusions can be drawn, and so render possible a clear conception of the composition and quantity of dusts produced in the operation of dry rubbing down.

THE DRY RUBBING DOWN PROCESS.

The method of dry rubbing down as usually adopted consists of rubbing a painted surface (new or old) with an abrasive in order to smoothen the surface prior to the application of a coat of paint. The abrasives now in use are flint, emery, glass, garnet, sand, etc., affixed to paper or fabric by means of glue. When rubbed on a painted surface these abrasives remove surface irregularities, producing a powdery material known as "paint dust." Paint dust is a mixture heterogeneous in respect of size of components, and when freed from the painted surface, the large or heavy particles fall rapidly to the ground, or are arrested in their fall by horizontal or similar surfaces on which they can lodge; the finer particles behave in a similar way, but fall much more slowly, and the finest remain suspended in the air for long periods. Dust not projected from the painted surface or dust settled on the work is removed by a brush—the operation being known as "dusting." Surfaces when dusted are ready for painting.

The remarks made by Armstrong and myself(2) on this process adequately sum up the general position:—

"Large quantities of dust are produced in this operation, as is well-known to those who have interested themselves in the matter. It is questionable, however, whether those actually engaged in the operation do appreciate the risk they run. We recently had a room dry rubbed down, making no remark: we found that the painter was wholly indifferent to the fact that his hair was powdered white and that his tracks were visible over the floor of the room."

It is the custom of operative painters to wear white overalls, and these, I find on enquiry, are changed weekly or when "dirty"—"dirty" apparently meaning discoloured. As much "paint dust" is white it is not readily detected at sight on a white overall and the extent of contamination is unknown. Frequently, it must happen that a clean overall becomes charged with paint dust so soon as it is worn, and its continued use until the week-end or until it is "dirty" means that the painter is carrying on his person a store of loose paint dust, which, when disturbed by his movements, enters the air and may be breathed.

The production of dust in the dry rubbing down process is indeed obvious, but its quantitative production has seldom been investigated. The significance of the methods of expression of results adopted in this paper will be appreciated when it is stated that in the Majority Report of the Home Office Committee on Painting(3), it is concluded that

"It therefore follows that some figure between 2 and 4 milligrammes of lead per 10 cu.m. represents the maximum extent to which the atmosphere may be vitiated without becoming a source of lead poisoning."

This, is based on the opinions of Dr. Legge and Sir Kenneth Goadby(4) who found that

"Somewhere about 2 milligrammes we regard as the lowest daily dose which, inhaled as fume or dust in the air, may, in the course of years, set up chronic plumbism."

Before detailing the figures obtained in my experiments, the following results of others may be quoted. In Austria(5) it was found that in one case where fine white work was being rubbed down, the lead content in the air breathed by the worker engaged in rubbing down, and the operations connected with it, varied from 88.5 to 250 milligrammes per $10m^3$ of air. In another case, where, in addition to white work, light imitation oak work was carried out, the lead content varied from 23.7 to 56.7 milligrammes per $10m^3$. In the first case, the time occupied by the worker in rubbing down represented one-third of his whole time, whilst in the second case it varied from one quarter to one third.

In England, a valuable set of determinations have been made by Mr. G. E. Duckering(6), whose results show that in coach and carriage painting, the concentration of dust in the vicinity of the worker's mouth reached 1343 milligrammes per $10m^3$ when engaged in dusting. In sandpapering the same surface, the dust content was found to be 453 milligrammes. In this particular case, the paint used was a quick drying white lead paint. In other determinations, Duckering has found that the concentration of dust in the air at the worker's mouth during sandpapering and dusting varied from 61 to 615 milligrammes per $10m^3$.

Experimental Investigation of Dry Process.

To obtain knowledge as to the character and quantity of dust produced, a large number of dust determinations have been made in which air in the vicinity of the worker's mouth was drawn through a filter, which was weighed before and after the operation. The quantity of air passed through the filter being known, it was possible to make comparisons between quantities of dust produced in different operations.

In this paper, the expression "dust figure" will be used as suggested by Roos(7) and must be taken to represent the quantity of dust which is likely to be breathed by a worker as distinct from the quantity of dust which may actually be in the air in the vicinity of the worker's mouth. It is important to draw attention to this, because it is often assumed that the quantity of dust collected represents both the actual dust content of the air and the quantity inhaled by the worker. In point of fact, this is not the case, because the quantity and quality of dust taken into the filter is directly affected by the velocity of aspiration. It is clear that particles may fall past the inlet of the filter (and equally at the mouth of the worker) at such a velocity or be of such a weight as will not permit of their being drawn into the filter, and so the velocity of air entering the filter should approximate to that of air inhaled by a worker, in which circumstances, the results obtained have more practical value than figures representing the total dust content of the air. This point has not been sufficiently appreciated in the past.

There is definite evidence of selection by air currents in particles of paint dust falling in moving air as is shown in the work of Mr. Duckering, who found that the dust in air at the breathing point of a worker sandpapering and dusting wooden

motor wheels contained 44 per cent. of lead, whereas the dust obtained when the same wheels were sandpapered and dusted under an exhaust contained only 13.3 per cent. lead.

The following figures have been chosen from a large number of determinations of dust which have been made under my supervision. Reproduction of the whole of the figures is unnecessary, as it would result in much redundancy and, therefore, typical examples have been selected to illustrate the different effects which have been observed.

Influence of Age of Film.

(White lead paint, medium gloss of same composition using same glass paper).

Rubbing and Dusting.

	Age of Film.			
	1 day.	8 months.	2 years.	8 years.
Dust figure (Pb mgrm. per 10^3m)	21	453	611	—
Percentage lead (Pb) in above dust.. ..	65	12.8	17.3	—
Percentage lead (Pb) in dust falling to floor within 4″ of rubbed down vertical surface	33.6	49.6	44.5	25.1

Influence of Variation in Paint Surface Films Three Days Old.

Rubbing and Dusting.

	Glossy.	Medium.	Flat.
Dust figure	66	247	455

Variation in Type of Abrasive Paper when used on Surfaces Similarly Painted.

	No. 2. F. Glass.	No. 2 M.	No. 1.
Dust falling to floor—percentage of lead in ..	49.7	48.1	45.6

Comparison of Dusting-off and Sandpapering.

Dust Figures (mgrm Pb per 10^3m).

	Sandpapering	Dusting.
Using even vertical surfaces.	38	11
Vertical surfaces with horizontal ledges—panelled work ..	42	432

Composition and Quantity of Dust Settling at Various Distances from Vertical Surface when Dry Rubbed Down.

	Distance from vertical surface rubbed down (inches).				
	0–20	20–50	50–80	80–110	110–140
Weight of dust collected: mgrm. per sq. in.	5.4	0.63	0.12	0.07	0.09
Percentage lead in above dust ..	36.6	8.9	11.9	8.6	8.5

Dust Created During Cleaning and Sweeping Settled Dust.

Dust Figure—(mgrm. per 10^3m)	512

These results clearly illustrate the many variations which are to be expected in this type of investigation, yet all clearly demonstrate the production of considerable quantities of dust during the process of dry rubbing down. Summarized, these investigations show:

1. With hardening of the film, due to ageing, the quantity of breathable dust created is increased. Also, that the percentage of lead present in the dust near the worker's mouth is increased, whilst that in the dust falling to the floor does not vary appreciably. With films which are not hard the dust mats together, forming comparatively large pieces which fall rapidly.

2. The presence of material, other than paint material, is obvious in all cases, and it is to be noted that the quantity of foreign material present varies according to the character of the film, *i.e.*, glossy or flat.

3. The type (grade or size) of paper does not appear to have much effect upon the composition of the dust produced, although the size of the particles of abrasive on the paper is directly related to the size and quantity of the small particles of abrasive appearing in the paint dust.

4. Either sandpapering or dusting may in different circumstances cause most dust. There appears to be no useful purpose served by classing these two processes separately. It is quite clear that in the sandpapering of vertical surfaces, by far the greater part of the dust falls to the ground, and will not appear in the dusting operations, whereas when the surfaces are wholly or in part, horizontal, the dust created during sandpapering collects and its subsequent removal in the dusting operation gives rise to a concentration much greater than is the case with vertical surfaces.

5. The dust created during dry rubbing down, travels considerable distances from the surface at which it was created and it has been detected at distances up to 12ft., the size of the particle and concentration of the same, decreasing with increased distance.

6. The material falling to the floor is a source of serious dust production when disturbed by the movements of painters; it should be removed in a wet state immediately after production.

7. In addition to the foregoing, it is desirable to place on record observations made recently during a spell of wet weather. Paint dust as inhaled by the worker was required, and in order to obtain this, a painter was requested to dry rub down painted woodwork and plaster, whilst a filter aspirated air in the vicinity of his mouth. At the end of the operation the filter was found to be practically free of dust, despite the passage of a large volume of air. On investigation it was found that owing to the humid state of the atmosphere the surfaces were damp, indeed wet, and such paint as was removed from the surface was in the form of large clots. Further, the glass paper used was rapidly covered with matted paint dust, thus being rendered ineffective. The influence of quite small quantities of water in preventing the liberation of dust in this way, is altogether remarkable.

It must be pointed out that the many and varied conditions incidental to the process, if investigated individually, would be extremely numerous, and it is now clear that the results obtained would not justify the expense in time or material. It is, however, necessary to make numerous determinations, otherwise the results are likely to be misleading, as in a limited investigation there might be circumstances preventing the evolution of dust in quantity so giving a wrong picture of the dangers of the process. I feel that the true position is perfectly clear from the work already done.

It has been suggested that the time spent by the painter in rubbing down is but a small part of the time during which he is employed. This is true in many cases, *e.g.*, certain classes of house painting, yet it must be borne in mind, as already stated, the clothes of the painter become charged with paint dust, collected during the dry rubbing down process, and his body movements liberate dust lodged in his garments. This point has been definitely demonstrated by Sir J. J. Dobbie (8) and myself (9) in the examination of overalls of painters engaged in general painting work. Dobbie found the quantity of loose dust present in 40 garments worn by painters for one week to be equal to 10.9 milligrammes PbO per day per worker, whilst in a separate investigation made by me on the overalls worn by twelve painters, the figure was found to be 12.9 mgrm. PbO per day per worker—these figures do not show the maximum concentration of dust during

the working period, but represent only average figures for "dirty" garments, *i.e.*, garments which had been worn for one week and from which much of the loose dust must have been removed in the course of the painter's work.

In order to demonstrate the quantity of dust which falls on a painter's clothes engaged in dry rubbing down, a painter was provided with black overalls made of paper rendered slightly sticky so as to fix all dust falling thereon. The face was covered by a mask, having holes for the eyes. Interior paint seven years old was rubbed down—one panelled door, two window frames—the operation lasting 45 minutes. The result is before you, and leaves no doubt as to the quantity of dust which may collect on a worker's clothes and yet be invisible. The dust is distributed as follows:—most dust is collected on head, right shoulder and right of back, right forearm (much concentration at wrist); lesser quantities collect on the left forearm (concentrated at wrist), right side of stomach and under right arm and on boots. The dust on face is small in quantity but is regularly distributed: similarly on shoulders and chest. Front of boots are covered lightly with dust.

Discussion of Results of Dry Rubbing Down Experiments.

The foregoing figures clearly demonstrate the grave dangers which attend the use of the dry rubbing down process, and no further argument is required for its discontinuance.

It will have been observed that all the figures relating to paint dust reveal the presence of materials other than normal constituents of the paint film. In view of this, it is somewhat curious to find the general assumption that the action of pigments and paint dusts are similar, for with but one exception, all animal experiments have been made by using the pure pigment. The only animal experiments in which paint dusts have been used are those of Carlson and Woelfel (10). The experiments being feeding experiments resulted only in the study of gastro intestinal absorption, the much more important channel of infection, viz., the lung being disregarded. In the experiments of Carlson and Woelfel, the paint dusts used by them do not appear to have been similar to dusts produced in ordinary painting practice—the percentage of pigment present being much higher than is usually found.

Inhalation experiments have been entirely confined to a study of the effect of pigments and not paint dusts, and this method of enquiry has been a serious limitation of the scope of investigations, for in the place of complete investigations as to the composition and effects of paint dusts, deductive reasoning has been substituted in which it is assumed that the dangerous character of paint dust lies solely in its metallic constituent.

It is important to draw attention to the experiments of Carlson and Woelfel (loc. cit.), as showing the protective action of the vehicle in determinations of the solubility of paint dusts in gastric juice. The solubility of basic sulphate of lead paint dust as compared with that of the pure pigment was found to be (corrected on a basis of equal quantities of pigment present) as 10.7 : 24.7. In the case of white lead, the relative figures are 46.1 : 59.8. It is thus clear that the influence of dried vehicle is important.

No complete analyses of paint dusts have, to my knowledge, been published, and Armstrong and I(11) called attention to this fact in referring to the figures of Mr. Duckering(12). We pointed out that these figures had particular interest because they showed that the dust in the vicinity of the mouth of the painters engaged in sandpapering and dusting surfaces which had been painted with white lead paint, contained, in many cases, comparatively small quantities of lead, the actual percentages being 13.3, 15.2, 15.4, 26.1, 30.6, 41.5, 42.0, 44.0, 46.2, 48.1, 65.9, and in single determinations, 76.2 per cent. for dusting and 18.3 per cent. for sand papering. Had the paint dust consisted solely of dried paint of the composition usually applied, the lead content would have varied between 60 and 70 per cent., although as must be pointed out, the undercoats of some of the surfaces sandpapered during Duckering's experiments did not consist wholly of lead pigment, yet the exterior coat appears to have consisted of lead paint, therefore, the figures can be taken as representing the dusts produced in the rubbing down of lead paints.

I have made a large number of analyses of the paint dusts produced in the course of this investigation, and have invariably found abrasive material to be present in

quantity. The abrasive materials, from which so-called sand, glass or flint papers are made, consist of glass, sand, powdered flint, garnet, hard slags, etc., and these materials usually contain a high percentage of silica (free or combined).

The numerous investigations made during recent years in respect to industrial pneumonoconiosis, especially silicosis, have elucidated many hitherto unexplained variations in respect to occupational diseases attributable to the inhalation of dust. Collis([13]), in his Milroy Lectures, regards crystalline silica as the principal source of dust phthisis, and states that the amorphous form of silica and silicates is harmless. He indicates that silica dust consists of particles of small size (so that they may be carried into the alveoli), which are hard and angular and, therefore, capable of acting as centres of irritation. According to Collis, these particles are chemically acid, and, owing to the presence of the element silicon, may render particles capable of entering into and modifying the colloidal structure of protoplasm; and finally have smell, possibly due to a vapour as yet undetermined, which is given off when silica is fractured. Drinker([14]), discussing these conclusions, remarks that "we do not know which, or whether any, of these properties is responsible for the harm done by silica."

From the standpoint of industrial hygiene, such knowledge is essential, but in considering any specific occupation, it is important primarily to determine whether conditions do arise where exposure to such dusts is possible, and the question at once arises—does paint dust, as breathed by the painter, contain free silica in the form and size regarded as dangerous?

Experiments designed to investigate this point have demonstrated the presence of finely divided particles of abrasive below 1 μ and up, in paint dust created during the dry rubbing down of painted surfaces. The quantity of abrasive obtained varies not only with the hardness of the paint film, but with the size of the abrasive material. Particles as small as 4 μ may frequently be detected in new papers before use. Microscopic examinations of paint dust obtained in the dry rubbing down of paints show the abrasive to be present in all sizes of particles, from particles equal in size to the maximum contained on the paper, down to sizes below 1 μ. It is obvious that large particles of dust cannot enter the lung, and such particles must, therefore, be disregarded. Apparently, particles less than 6 μ in diameter are regarded as the most dangerous, and, therefore, data referring to dusts should include enumeration of the various sized particles present in order to be of real value.

Middleton ([15]) rejects as unimportant all particles having a maximum diameter greater than 12 μ and states that the majority of particles found in the lung are less than 2 μ. Further, over 50 per cent. are less than 1 μ, whilst few are over 3 μ. He points out that mere gravimetric estimations of the different sized particles are misleading, because they underestimate the dangerous properties of a dusty atmosphere, thus a single particle of 100 microns diameter weighs the same as 125,000 particles of two microns diameter: the former, on account of its size, is non-injurious, whilst the latter are extremely injurious. Smyth and Iszard ([16]) state that particles most frequently present in the lung, have a diameter of 1 micron, and that 60 to 80 per cent. of the particles present lie between 1 and 5 microns. They emphasise the fact that it is doubtful whether the finest particles are the most dangerous and consider that, other things being equal, with all microscopic foreign bodies, the larger the body the greater the irritation produced, and that with soluble toxic particles the larger are the more toxic.

It is interesting to note that the importance of size in reference to the particles drawn into the filter is now being appreciated. This appears to be especially necessary where the danger of the dust lies in its action on or in the lungs, and it would appear that only particles of 12 μ and less should be considered as dangerous.

In the results obtained by Roos in the determination of dust in the air of printers' workrooms, it is noted that in the only four samples in which silica particles were examined, the size of the particles varied from 4 μ to 40 μ. Obviously the latter are unimportant as they cannot enter the lung.

Chemical analyses alone of dust collecting in workrooms, on ledges, etc., do not necessarily indicate the dangerous character of dust which may be inhaled and, in order to obtain a true idea of the dangers of any dust in relation to respiratory disease, analysis should be based on particles less than 12 μ in diameter. Dusts often contain

particles of various sizes, and it cannot be presumed that the chemical composition of the different sized particles is identical, for in many cases, they are mixtures of a number of products of varying chemical composition and size.

All abrasives used for paint rubbing make appearance in the paint dust, and although it has been shown that dust of crystalline silica is the most dangerous, it cannot be assumed that the dust of other abrasives is without effect on the respiratory system. Reynolds (17) has described the existence of a fine tube bronchitis, especially prevalent amongst those exposed to dust of emery and glass, and Collis (18) has pointed out the necessity for detailed investigation into the effects produced by these dusts.

Respiratory Disease Amongst Painters.

In view of the prevalence of respiratory diseases amongst workers exposed to siliceous dusts, it was considered of importance to ascertain whether or not the painter suffered in a like manner. The following figures show that this is the case.

English Painters' Deaths.

The increased death rate of the painter from phthisis was emphasised by Dr. Collis (19) in his evidence before the Departmental Committee on the "Use of Paints Containing Lead in the Painting of Buildings" (pages 112 to 115), the data on which he based his statement being drawn from the mortality statistics of the National Amalgamated Society of Operative House and Ship Painters and Decorators, 1905 to 1910, and the Scottish Society of House Painters, 1901 to 1910.

Dutch Painters.

According to Oliver (Bulletin 95) (20), the percentages of deaths among painters due to phthisis in the Netherlands, is excessive. The following table, due to de Vooys, shows for different age groups, the percentage of deaths due to phthisis occurring among painters and all trades.

Age Groups.	House Painters.	All Trades.
12-17	3.87	2.70
18-22	14.82	11.96
23-35	15.54	12.40
36-50	15.87	11.25
51-60	16.64	12.16
61-65	14.86	11.22
66-70	19.36	11.0
71 & over	4.92	6.80
Average	13.85	10.65

American Painters.

Thompson (21) refers to the report of the New York State Bureau of Labour for 1906, in which plumbers, glaziers and varnishers are shown to have a death rate of 3.19 per 1,000 from phthisis, whilst occupations such as boot and shoe makers, machinists and millers have death rates of 1.35, 1.95, 1.98 respectively.

Dr. Alice Hamilton (22) quotes the results obtained by Hayhurst in the examination of 100 American Painters, of whom 20 showed signs of lung affections, viz., 7, emphysema; 1, acute bronchitis; 14, no active tubercular lesions, but all suspicious.

The following figures taken from the United States Registration Groups, 1908 to 1909, are quoted by Winslow and Greenburg (23) and show ratio in percentage of deaths due to tuberculosis to all deaths for painters and all occupied males.

Class.	Deaths due to Phthisis stated as percentage of all Deaths.	Median age at death due to	
	Phthisis.	All causes	Phthisis.
All males* (England and Wales, 1900-2)	11.11	56–57	39–40
Plumber, painter, glazier*	18.36	48–49	38–39
Painter†	15.72	48–49	38–39

*Calculated from the Supplement to the Sixty-fifth Annual Report of the Registrar General for Births, Deaths, and Marriages.

†Calculated from the mortality statistics of the National Amalgamated Society of Operative House and Ship Painters and Decorators, 1905-10, and of the Scottish Painters' Society 1901-10.

	Ages.					
	15–24	25–34	35–44	45–54	55–64	65 & over
Painter, Glazier & Varnisher	30.8	36.9	29.2	17.4	9.0	18.7
All occupied males ..	28.1	30.9	24.0	14.0	7.6	14.9

Louis I. Harris(24) in "A Clinical Study of the frequency of lead, turpentine and benzine poisoning in 400 Painters," found that a total of 98 or nearly one quarter of all the painters examined, gave a history and physical signs of chronic bronchitis and in discussing this suggests that interior painters who are exposed to the fumes of turpentine, benzine and other volatile irritants, are particularly subject to the developments of tuberculosis, and the tendency to emphasise the importance of dust and to overlook the predisposing influence of irritant agents should be guarded against. Harris was evidently unaware of the presence of particles of silica in paint dusts, but his suggestion of the irritant effect of volatile agents is worthy of consideration.

Sir Kenneth Goadby (*Lancet*, 1921, II., 489) gives a table showing the figures of illness suffered by painters belonging to the Sickness Benefit Branch of the Hearts of Oak, and states that from the table, it would be seen that the chief diseases from which the painter suffers are those of the respiratory tract—the respiratory diseases comprising influenza, phthisis, bronchitis, pneumonia and other diseases of the respiratory organs. Further, he states, that "comparison of the disease occurring in white lead workers who work in lead alone, uncomplicated by the dust of angular particles, shows that while respiratory diseases are common in potters, who inhale flint dust and lead together, it is not so common amongst white lead workers who only inhale lead dust. The material of which the painter makes use is soft and not angular, and it is well known that persons exposed to baryta and other types of dust without angular particles, do not show the high incidence of respiratory disease. The painter, on the other hand, is exposed to a risk to which neither of the other classes is exposed—namely, the inhalation of fumes of volatile products (turpentine and turpentine substitutes) which are known to produce respiratory effects in susceptible animals."

Thus, it will be seen that Sir Kenneth Goadby and Dr. Harris are in agreement in attributing the high incidence of respiratory disease in painters to the inhalation of the vapours of volatile thinners and overlook the fact that the dusts produced in the dry rubbing down of paint, contain particles of abrasive which are hard and angular. Also that barytes, silica and other paint constituents of paint material are hard and angular.

In a recent report(25) issued by the New South Wales Government as representing the findings of a Committee appointed to investigate the question of lead poisoning amongst painters, it is clear that the Committee realised the possibility of ill-effects being caused to the painter through inhalation of silica dust: it is stated:—

"The amount of silica inspired by the painter must be proportionately small. He is not rubbing down all of his working days, or every working day, and the dust produced by the process of rubbing must be largely metallic and organic as well as siliceous. Yet it may well be that the comparatively small amount of silica in the dust which he inhales is made, for those of his class who are non-resistant to lead, particularly noxious to the lungs."

It appears that there is sound evidence of a high incidence of respiratory disease among painters: that this is not due to the action of lead, is definitely stated by Legge and Goadby(26), who find that:

"Neither phthisis nor pneumonia nor acute disease of the heart or lungs or valvular disease of the heart nor indeed any febrile condition can have direct relation with, *i.e.*, be a sequela of, lead poisoning."

More recently Goadby(27) has stated:

"In the systematic examination of three large lead factories during the last 20 years, the average total of persons employed numbering about 500, I have seen no case of tuberculosis, and yet the factor that all these workers are exposed to is lead dust inhalation."

I therefore suggest the urgent need of an enquiry into the relation between respiratory diseases of the painter and the sharp dusts of abrasives which occur in paint dusts. Material for such an enquiry is readily available and X-ray examination of coach painters engaged in the dry rubbing process, would doubtless be instructive.

The desirability of such an enquiry cannot be over estimated, for the increase in ratio of phthisis in the painter over that of all occupied males, is greater than the total number of deaths from lead poisoning amongst painters.

Consideration of the foregoing facts impressed on me the vital need for the introduction of a dustless method for the rubbing of painted surfaces, and in consequence, I commenced work with that end in view. The following is a record of the work carried out and results obtained.

The Wet Process of Rubbing Down.

The wet process of rubbing down which has been in practice for many years, is operated in the following manner: the painted surface is wetted with water and then rubbed with pumice (powdered or lump), cuttlefish or other abrasive until an even surface is obtained, after which the surface is washed in order to remove the mixture of powdered paint film and abrasive. The surface when dry is ready for repainting. It is generally stated that no dust is created in the wet process, and the use of this method, particularly for surfaces painted with lead paints, has been extensively advocated, but is by no means in general use. I was informed by painters that the process was not capable of general application, because:

1. New paint films (*i.e.* intermediate coats) were fragile and would be torn if this process was applied. Further, it was the general opinion that no hygienic necessity existed for the adoption of wet processes in the case of new paint films because it was considered that the operation was a dustless one.

2. The spilling of water and the accumulation of wettedpaint dust made this process unsuitable.

3. That with pieces of pumice stone or cuttlefish, it was impossible to rub down curved surfaces and adequately to rub the intricacies of moulding. With glass paper, this was possible, because the paper could be shaped and folded in the required manner.

4. The period required for the drying after application of water was so long as to interfere with the regular cycle of painting operations when carried out in house decoration or similar work—much of which has to be done quickly.

In September, 1921, I discussed these matters with certain representatives of the National Federation of Master Painters who had given serious consideration to the question of lead poisoning, and were anxious to adopt such precautions as were necessary and at the same time practicable, in order to prevent the production of paint dust. I found that the representatives were prepared to accept as compulsory the process of wet rubbing down for all surfaces over three months old, retaining, however, the process of dry rubbing for surfaces up to that age. In justification of this, it was considered that the fragile character of the film up to three months, rendered the wet process impracticable, and further, that dust obtained by the dry rubbing down of films up to that age was free from pigment, and that such dust as was created consisted solely of fine dust from the abrasive, it being supposed that the paint material matted and fell to the floor in large pieces. When I demonstrated to them that breathable dust was readily produced in the rubbing down of new paint films, it was suggested that the three month period might be reduced to seven days. I could not accept this suggestion, because experimental work had shown that even with films 24 hours old, a dangerous amount of paint dust was at times produced, and I was, therefore, compelled to seek a process which, whilst being dustless, would be accepted as practicable by those engaged in the painting trade.

The Damp Process of Rubbing Down.

To this end, a large number of experiments were made in the laboratory and these resulted in the development of a process of damp rubbing down in which ordinary sandpaper was substituted for the powdered or lump abrasive used in the wet process. In this method the painted surface is damped by means of a sponge wetted with water, and is then immediately rubbed with abrasive paper followed by sponging with a clean wet sponge to remove paint and abrasive materials in a dustless condition. The rubbed and clean surface is then allowed to dry prior to painting. The novelty* in this process consists in the use of a limited quantity of water and the application of ordinary sandpaper.

*My attention has been drawn to the fact that in evidence tendered before the Departmental Committee of the Home Office on Painting, Cd. 7882, Mr. J. Sibthorpe, of Dublin, stated that the wet process could be applied if waterproof sandpaper were used and that although it was then not available he could supply a formula for its manufacture. I was unaware of this fact until long after the efficiency of the damp process had been demonstrated by myself and others, and Mr. Sibthorpe has been good enough to express his keen appreciation of the developments which have taken place and expresses the hope that the New Irish Parliament will, at an early date, prohibit the dry rubbing down process.

The limited quantity of water prevents splashing of water or paint dust, the period required for drying is shortened, the whole of the "dust" is removed by sponging in a non-dangerous condition and is ultimately obtained as a sludge settling from the water in which the sponge is rinsed. Numerous experiments have shown that the "dust figure" in this process is entirely negligible: in few cases has the quantity of dust determined been greater than that contained in the air of the room before the experiment was made. In two experiments, minute quantities of lead have been detected in the dust when white lead paint has been rubbed down, and it is probable that this lead was due to paint dust created by operatives handling planks, ladders, etc., which had been previously used in the dry-rubbing down method:—the total dust found in these experiments being 20 milligrammes per $10m^3$ and 38 respectively, containing 1.0 and 0.95 milligrammes of lead.

It is the opinion of expert painters that the surfaces obtained by this method are smoother than those obtained in the dry process, the reason for this being readily seen by microscopic examination of the paint dusts. The dust produced in the dry rubbing down process, particularly in the case of new paint, shows the film has been torn from its surface in pieces of appreciable size, which are rolled together in the form of clots. In the sludge obtained from the wash water in the damp process, the dust is found to be more regular and much smaller in size of particle, indicating a more gentle and regular action of the abrasive, possibly due to the water acting as a lubricant. It was found possible to apply the process to all painted surfaces, even with paint only 24 hours old.

In the case of the first coat of paint on wood there is a slight tendency for the grain to be raised if the process is applied too quickly after the application of the paint, but this does not apply to succeeding coats, and, if the priming coat is allowed to harden properly, this effect is not observed. As it was suggested that there was a possible risk of lead being absorbed from the powdered paint film during the washing of the sponge in water, the question was referred for medical opinion on this point. It was found that medical authorities* are generally agreed that in the circumstances described, absorption of lead through the skin would not take place, and no danger need be feared in this connection. It is quite clear that a painter should wash after the operation of sandpapering lead paints, whether the operation be done by the wet, damp or dry method, as otherwise the risk of lead being carried to the mouth with food or in smoking cannot be ignored.

Laboratory demonstrations in the hands of a practical painter having satisfied me that the process was worthy of large scale trials, I was fortunate in securing the co-operation of two well-known craftsmen, viz., Messrs. J. H. and W. H. Cantrill, of Manchester, who undertook to decorate a room and to paint a number of doors, using the damp method of rubbing down. This trial, which extended over some ten days, was carried out by operative painters, in the presence of painting experts, both Master (Mr. J. E. Butterworth, of Oldham, representing the Master Painters' Association), and Operatives. The process of damp rubbing down was explained to the operatives, who quickly grasped the points of the method, and this method was applied to all work. In all other operations, the methods of work were normal and mutually decided by Masters and Operatives without reference.

This demonstration proved entirely successful, and the efficacy of the process was established. The National Federation of Master Painters of Great Britain, expressed their approval of the process as practicable and empowered their representative (Mr. J. E. Butterworth) at the International Labour Conference at Geneva, to accept the process of damp rubbing down as a compulsory obligation in the use of white lead paints. Trials were made in London by Mr. Cecil Campbell, of Messrs. Campbell, Smith & Co., and these proved to be equally satisfactory.

In October, 1921, the Salvation Army Hall, Rochester Row, Westminster, S.W., was painted throughout by Messrs. John Barker & Co., Ltd., Kensington, using the damp rubbing down method. Whilst the work was in progress, visits were paid by a number of experts who pronounced their satisfaction with the method as then operated. The operatives of Messrs. Barker & Co., at once appreciated the hygienic advantages and practical ease of the process, and were amongst its most

* Penetration of lead directly through the skin is without any practical importance, but in many ways lead can be deposited on the skin, and be carried thence to the mouth. (vide Report of Medical Sub-Commission of White Lead Committee. Int. Lab. Con. Geneva. 1921.)

ardent advocates. In the Manchester and London demonstrations, all kinds of surfaces were worked upon and the paints used were lead and zinc paints, in addition to certain proprietary paints. Glossy, flat and enamel finished were tried and proved to be satisfactory in all circumstances.

The considered opinion of the Master Painters is that the increased cost of the process will be negligible.

The process was demonstrated to the Association of Master Builders of Great Britain, in London, in October of last year, and in the same month, before the National Association of Master Painters on the occasion of their annual convention at Harrogate—again, in both cases, the process received approval.

In the first experiments, ordinary glass-paper was used, *i.e.*, glasspaper on which the abrasive is fixed to the paper by means of a water soluble glue, and it was found that owing to the action of the water on the glue, there was a tendency for the abrasive to be detached from the paper. The extent to which this took place, varied considerably and even with ordinary glasspaper, the life of the paper was much longer than might have been expected, although the irregular manner in which some paper behaved indicated the desirability of a waterproof abrasive paper.

Waterproof Sandpaper.

Immediately prior to my departure for Geneva to attend the International Labour Conference in October, 1921, I received samples of an American waterproof paper which was then in the experimental stage. These samples proved to be a distinct advance on ordinary sandpaper, and later samples have been of such a quality that it may be said that a perfect waterproof paper is now available. The material is impervious to water, pieces chosen at random having been immersed for six months without any deterioration in the quality of the paper or loosening of its abrasive. The waterproofing in no way affects the cutting properties of the abrasive. The paper has a much longer working life than ordinary paper applied in the dry method, as is shown by the fact that the quantity of abrasive removed from the paper for an equal area of paint surface rubbed, is, in the case of waterproof paper, less than one quarter of that removed from ordinary paper when used in the dry method. After the paper has been used, the paint dust can be removed from it by washing and the paper rendered available for further use.

In the summer of 1922 when a sufficient quantity of this paper was available, I submitted samples to leading Master and Operative painters in Great Britain and Ireland, and to certain Goverment Departments, inviting expert opinions as to the suitability of the paper for the purpose for which it was designed. In no single case did the paper fail to receive high praise, and those who made trials of the paper appear most anxious to obtain supplies in order to use it in their ordinary work. Arrangements are now being made for papers (both English and American) of this type to be manufactured in this country, and it is further proposed to make rubbing blocks, consisting of blocks of wood of various shapes and sizes to which is affixed a layer of waterproof abrasive material. The paper is capable of being used in the dry, damp or wet processes and meets all possible objections in respect to the rubbing down of curved surfaces. Waterproof paper was used in the demonstrations made in London and Harrogate in October, 1922.

Conclusions.

It is clear that all the objections raised by the Master Painters to the ordinary wet process of rubbing down have been met by the now suggested damp process, because:—it is applicable to new paint; there is no spilling of water and no accumulation of wet paint dust on the floors; any surface which can be rubbed down with ordinary paper can be equally rubbed down damp with waterproof paper, and finally, the limited amount of water used, although sufficient to lubricate the abrasive, prevents dust and does not entail long delay in drying; further, what is of equal importance, the process is free of danger to the worker. In these circumstances the official approval of the National Association of Master Painters is a logical consequence.

It has been suggested in the United States that the dry rubbing down process can be replaced by one in which mineral oil is applied to the surface before sandpapering. This process does not appear to have any advantage over the damp process in which the use of water is advocated, nor does the same appear to be in use in this country to any appreciable extent.

In the convention agreed upon by the International Labour Conference, held at Geneva in November, 1921, when the danger of the dry process was fully appreciated, it was decided (par 1c. Art. 5) that :—

"Measures shall be taken wherever practicable to prevent danger arising from dust caused by dry rubbing down or scraping."

In the light of my experience with the damp process, the words "wherever practicable" are unnecessary. It is of interest to note that the Industrial Joint Council, consisting of master and journeymen painters has, in collaboration with the Home Office prepared a set of working regulations for painters, to give effect to the Geneva Convention, and amongst these is one dealing with this point, viz., Reg. 3. (28) which reads :—

"Surfaces painted with lead paint shall not be rubbed down or scraped by a dry process."

I personally feel that the abandonment of dry processes for rubbing down is very desirable in respect to all paints. It is proved that finely powdered abrasive is present in the dusts caused by rubbing down of all paints, be they lead or otherwise, and if, as has been suggested, the high rate of respiratory disease among painters is to be rightly attributed to this cause, then by preventing dust, we shall reduce, not only the cases of lead poisoning, but at the same time, reduce deaths from phthisis—a disease which to-day claims more victims over the normal figure than does lead poisoning.

It is my duty to express my indebtedness to the numerous Master and Operative painters who have so freely given their technical assistance and kindly encouragement in this investigation. Without this assistance the practicability of the process could not have been demonstrated. For assistance in the scientific portion of this paper I desire to place on record my keen appreciation of the valuable help rendered by the Chemical staff of the Brimsdown Lead Co., Ltd., and in particular, Mr. William Hulme, who has been closely associated with me in most of the hygienic investigations made in the Brimsdown Laboratory during recent years.

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DISCUSSION.

THE CHAIRMAN (Dr. T. M. Legge) said that Mr. Klein's ingenious experiments, and his patience and persistence, which had characterised all his work, must excite general admiration. To himself this subject was deeply interesting, inasmuch as it represented a certain change of attitude, if he might so describe it, on the part of industry to the problems which it had to face. Time was when the occupier would wait for the factory inspector to tell him when to do a thing and what to do. That was a most dangerous attitude, but now the position was reversed, and the technical experts were doing all they could to assist in the progress towards the ideal which the factory inspectorate had at heart. No technical man had given his own department at the Home Office greater assistance than had Mr. Klein. The author's previous work had had a definite bearing upon the subject he had advanced that evening, because it showed the line of thought which he had pursued all through. The *coup de grace* was given practically to lead poisoning in the potteries through the patience and persistence of Mr. Klein; and,

still more recently, when, owing to the incidence of lead poisoning through dust in the mixing of indiarubber, the Home Office found it necessary to issue cast-iron regulations for the rubber industry, requiring exhaust ventilation, periodical medical examination, washing accommodation, and so forth, it was Mr. Klein again, like a conjuror, who so altered the conditions of the manufacture that, by a simple transformation from a dusty material into a non-dusty material, the employer was saved the indefinite expenditure and liability involved in all these arrangements. Moreover, although this was only brought out about July of last year, the number of cases of lead poisoning already had markedly dropped, and last year the number was smaller than it had been for many years past. Now Mr. Klein was adapting his scientific knowledge in the same practical way to bring salvation to a quarter of a million painters, of whom 150,000 were house painters. The speaker did not think that he would be there that evening in the position he occupied if Mr. Klein's work on the subject had ceased at the stage at which ordinary sandpaper and a sponge were used; when he got to waterproof sandpaper it became another story. Everyone was hopeful of this new procedure. He had waited to hear from Mr. Klein something about an aspect of the subject which particularly appealed to him, but he noticed that Mr. Klein had carefully avoided it. This had to do with the administrative side. The Factory and Workshop Act was quite a powerful piece of legislation, but it was not possible to drive even this, like a coach and four, through certain first principles which were in every Englishman's mind, like the one which declared that the Englishman's house was his castle. He was afraid that householders would not expect to receive calls from his inspectorial colleagues—very reasonable and affable people—nor from himself in their own homes. Whatever regulations were set up, there must always be weak links in the chain of inspection, and the only way of meeting the difficulty was by education of the operative and master painters themselves in order to prove to them that it was to their interest, and a good business proposition, to get rid of the dust created by dry sandpapering. To get them to see that the use of a wet rubbing down process was desirable might take some years, for it had to be realized that this was the first occasion on which it had been publicly mooted, that the process was only at its beginning, and that it was a lengthy matter to get rid of prejudices and bad habits.

He would like to add a few words of constructive criticism. He felt that the lure and fascination of scientific observation, pursued for love of science, sometimes carried the investigator away, and he could only think of a rather new-coined word to describe what followed—namely the word "Stunt"—with regard to some particular point. For example, the conditions of the atmosphere were investigated, certain things were regarded through not too convincing statistics, and the patient himself, the person chiefly concerned, was short-circuited altogether. He was not asked what he suffered from, no inquiry was made into the morbid anatomy of the case, it was said, *e.g.*, that silica dust was in the air, and as a form of phthisis was called "silicosis," therefore, all phthisis must be due to silica dust! There was an extremely interesting example of this kind of reasoning in the *Times* two years ago, (for the Press commented on all these "stunts" with avidity). The writer of the original letter in the *Times*, who was a medical man, was less positive than those who commented on his remarks with regard to printers' phthisis and silicosis, but these latter declared that because some silica was found in the air, that was the vehicle whereby phthisis was conveyed to the printer, whose phthisis was therefore silicosis. Everybody knew that far too many printers had died of phthisis, but he would venture to say that there never had been a printer who had died with the symptoms of silicosis. He begged that no similar "stunt" should be made with regard to fibroid phthisis and silicosis in the house painter. The poor house painter had quite enough to bear as it was, without being pursued either by turpentine poisoning or fibroid phthisis. The writer of that letter in the *Times*, when he was driven into a corner, had the good sense and right feeling to say, "Well, no matter, there is plenty of phthisis among painters. Let us do all we can to stop it." And that, he was sure, was the feeling that Mr. Klein also desired to convey in his paper that evening.

Sir Kenneth Goadby, K.B.E. (Medical Referee for Industrial Poisoning, County of London), said that after the last few remarks of the Chairman, in which he coupled fibroid phthisis and silicosis and turpentine poisoning, he felt that he must rise to protest. Perhaps he did not see eye to eye with Dr. Legge on the question of turpentine poisoning, and a good deal of statistical evidence had still to be obtained before he could persuade Dr. Legge to accept his point of view with regard to turpentine, but he was ready to endorse a good deal of what he had said with regard to fibroid phthisis. The other evidence in Mr. Klein's paper with regard to phthisis was much more valuable than the figures he had quoted which appeared to show that painters suffered from a large excess of phthisis. He thought that he (the speaker) might in some way be responsible for the initial suggestion that the silica dust in the sandpaper might be associated with phthisis if in fact the phthisis showed a high incidence; but there was not sufficient statistical evidence, to his mind, to show that there was in fact such a large excess of phthisis amongst painters, at any rate, of phthisis of such a type as could be accused of following upon the

presence of dust of this nature. Some aspects of the painter's occupation might predispose him to phthisis, such as exposure, for example, though it might be possible to turn the statistics the other way round and show that in consequence of his open-air life he enjoyed a relative immunity from phthisis! If the statistics of phthisis showed a progressive increase towards the later age groups, as in true fibroid phthisis, which was an old disease rather than an early one, they would expect to see in these figures a greater increase in the incidence of cases among the older men than was actually found. There were other diseases which were due to the painter's occupation—he thought certain forms of kidney disease—but he did not think that there was a definite increase of fibroid phthisis, to the extent suggested, among those who took occupational risks, either from silica or turpentine.

He would like to say how much he had been impressed by Mr. Klein's assiduity, also with that quality upon which Archbishop Whately laid such stress, the quality of perspicuity. He had been very clear in what he had told them. He had given them a very succinct outline of his work. But the speaker would like to make one little point of criticism. Mr. Klein had pointed out that no inhalation work had been done with lead dust, and, therefore, no conclusions could be drawn as to the action of lead dust and its relation to disease. He did not think that Mr. Klein could quite mean that, because the real reason for which any inhalation experiments were done was to determine whether lead poisoning was produced by inhaled dust. The question was whether, if poison particles gained entrance into the lung, they did in fact produce poisoning. One must admit that the chief industrial risk of the painter was lead poisoning, and that lead was one of the constituents of the paint. But a most important fact with regard to lead was that lead particles behave differently in different circumstances, according to whether they were mixed with one thing or another. There were many conditions which influenced the solubility of lead, and, therefore, its action on the body, and that was one of the important questions from the point of the hygienist. He was confining himself to the medical point of view in all that he had to say that evening, and from that point of view they were very much indebted to Mr. Klein for these careful considerations with regard to dust, and for his estimations of the relative quantity of poisonous material in the dusts. All these were very important. If he might be permitted one technical criticism, it would be that in connection with all these experiments carried out on collected air for the examination of dust, the arrangement provided for a mouthpiece of a size very much smaller than the human respiratory passages. A man might take a large gulp of air into his mouth. The small tubes used for obtaining air in which the contained dust could be examined were much smaller in cross section than the human breathing apparatus, and not only so but the process of breathing, which was intermittent, and took place so many times a minute, was not repeated in the same fashion in the method used to indraw air for these dust estimations. He thought that this was likely to have a certain bearing on the conduct of the experiments. He did not think that very exact knowledge was likely to be gained with regard to lead poisoning by inhalation experiments on animals by using paint dust. The mixed paint dust employed would contain all sorts of other materials in addition to lead, and the experiment would be complicated by irritant trouble produced in the passages. He doubted the usefulness of such experiments. It was important in all experiments to try to get the result within a reasonable time. An animal could be submitted to inhalation for a certain short period, but a man did not develop either lead poisoning or phthisis in a week or in a month. It would be very difficult, he thought, to adapt the paint film fragments, mixed up with silica and lead, to a straight experiment on these lines. He wished only to add how greatly he had been interested in the paper.

Mr. Alfred Rorke said that he understood the main object of that meeting was to discuss whether wet glass-paper was better than dry glass-paper. In his own view, most of the dust of white lead caused by glass paper was really the result of very bad painting. He deprecated alarmist statements on this subject; the idea should not be scattered abroad that this was a deadly business. Most trades had some element of danger in them. He instanced French polishing, which, he was told, was very dangerous, the fumes of the methylated spirit producing some of the effects of alcoholism, including cirrhosis of the liver. It would be interesting to know at what date glass-paper was first introduced, and what was done before it was introduced. The paper had struck him as being rather alarmist. If the painting trade was deadly, it was because of carelessness, and the best thing that could be done was to eliminate bad, rough, and careless painting.

Mr. C. E. Campbell wished to say how extremely interesting he had found Mr. Klein's paper, and to thank the Society for its courtesy in inviting master-painters to the meeting. It was not the first time that he had heard Mr. Klein speak on this subject, and his words must have opened the eyes of the master-painters generally to the danger of lead poisoning in the process of dry rubbing down. They had all been aware of the prevalence of lead poisoning among painters, but not many had realised how largely it was due to the dust that was produced from the dry rubbing down. The National Federation of Master Painters and Decorators of England and Wales had very carefully studied this

question, and its Materials Committee had been in close communication with the Home Office. When the Home Office regulations were issued they would have behind them the support of the master painters, and it would only be a matter of time before prejudice in any quarter would disappear. He had tried the process of damp rubbing down as advocated in the paper, and had found it entirely practicable.

CAPTAIN CARTER said that on many occasions they had listened with interest to lectures by Mr. Klein, in which his chemical and technical knowledge had proved very helpful. That night, however, they heard him in a new role, that of humanitarian. Mr. Klein had realised that for many years past plumbism had headed the list of industrial diseases, and consequently his effort had been directed to minimising the dangers of the process. Most of those who were connected with paint manufacture knew the danger of dry rubbing down, and many suggestions had been heard with a view to reducing the risk, for instance, the use of pumice-stone and water, sand-paper and linseed oil, and he had even heard of sandpaper and mineral oil being recommended. But while everybody would admit the danger arising from the use of white lead, very few, if any, would admit that the problem of lead poisoning amongst painters would be solved because America, once more conscious of her moral obligations and her duty to the civilised world, had come to the rescue! Did they need to turn to America in order to be shown how to look after the welfare of their fellow creatures? The problem of lead poisoning would not be solved by the use of a waterproof sandpaper manufactured in New York. It could only be solved once and for all by the putting into effect of the agreement entered into at the International Labour Conference at Geneva in 1921. At that Conference, delegates of (he believed) forty-two nations attended, and all agreed that as white lead was a poisonous pigment, the only satisfactory method whereby white lead poisoning could be eliminated was by the total prohibition of the use of white lead for inside painting. All these methods of rubbing down were not going, to the speaker's mind, to minimise the main trouble. If this sandpaper were put into the hands of the average painter, while he might take the necessary precaution of using the water for as long as he was being watched, he would ultimately revert to the manner of employing it to which he had been accustomed for the last twenty years.

MR. J. T. M. FARRIER spoke as an operative of 42 years' experience. He was rather inclined to think that the introduction of wet rubbing down, however well-intentioned the proposal might be, would be made a reason for side-tracking the object of the Convention—namely, the prohibition of the use of white lead. There was nothing new in wet rubbing down, and there was no doubt that dry rubbing down did have some tendency to aggravate the evils of lead. He was quite pleased to hear that at this late day some practicable and effective method had been arrived at. But, on looking through the annals of the trade, it was somewhat peculiar that so much glass paper should be necessary. All through his own operative career he had used as little of it as he possibly could, and he was inclined to think that its extended use was due to the introduction into the painting trade of those who had no real facility for the craft. The real painter was born, not made. It was of no use putting into the painting business a man who had lost his job as a butler! Men came into the trade at an age when their physique had deteriorated and was not fitted to stand the test of lead. The true painter entering the trade as a boy was possessed of a certain immunity against the occupational dangers. He pleaded for more respect for the craft, and for better tradesmen, men who had been trained from boyhood up.

PROFESSOR H. E. ARMSTRONG, F.R.S., offered the Chairman his congratulations on being able to be present on that occasion. Mr. Klein's paper described a piece of constructive work which should give general satisfaction. He was sorry that a reference had been made to that farcical meeting at Geneva. The tribunal was a preposterous one. The subject ought never to have been brought before it. The decision arrived at could have no meaning in the eyes of sensible men. Constructive action was called for, and of this the present paper was a token. What appealed to him was not only that here and there painters were very seriously affected by the dangers of lead, but also the fact that if lead were prohibited some 70,000 people in one community would be most seriously affected. That was a matter which had to be taken into consideration. Mr. Klein in regard to the lead problem, like Mr. Duckering in regard to the anthrax problem, had set an example for all time as to how these matters should be dealt with. He concluded by thanking the Chairman for presiding over the Meeting: no one had done more to bring about a right understanding on these matters than Dr. Legge.

MR. KLEIN, in replying to the discussion, said that he would like to endorse what Professor Armstrong had just said with regard to the Chairman. It was a great pleasure to see Dr. Legge in the Chair that evening, for no one in this country had contributed to anything like the same degree towards the solution of problems of industrial disease. In white lead factories there were now only one-twentieth of the cases of lead poisoning that there were when Dr. Legge first came into his position. The speaker could not give the whole credit to Dr. Legge, but the lion's share of it was his. Dr. Legge

had been able to persuade manufacturers to do the right thing. Twenty years ago when Dr. Legge became Medical Inspector of Factories, industrialists were not accustomed to be overridden by Government Inspectors. Dr. Legge's way was such that he enlisted the sympathy of the manufacturers and made them realise that he was out to assist rather than dictate without reason.

Dr. Legge, notwithstanding his praise of the speaker's work, had referred to the suggestion in reference to the cause of painter's phthisis as a "stunt." He (Mr. Klein) must protest against this remark, for "stunting" was not one of his habits. It had been definitely proved that dust from abrasive materials was inhaled by the painter and further, that painters have a high phthisis rate, and in view of this it was suggested that these facts warranted an enquiry into the possible relationship between dust and phthisis in the painters' trade. Nothing more than this was claimed, and even if on investigation it was found that the two facts were unrelated, such discovery would be a step forward, for whatever the cause, painters have a high phthisis rate and discovery of the cause by the process of elimination of possible sources was entirely scientific in method. As to printers' phthisis, the position was reversed: phthisis was known to exist amongst printers, but recent work had shown that silica was not the cause, because when the air of printers' rooms was examined, chemists were unable to demonstrate the presence of silica in excess of the normal quantities found in ordinary air.

With regard to the remarks of Sir Kenneth Goadby, the speaker's suggestion had been that when time permitted, the properties of paint dust as such, ought to be investigated, for, after all, the painter was poisoned by paint dust and the material which poisoned him must be studied in its entirety and not in respect to any one constituent. With regard to the criticism as to the size of the inlet of the air collecting apparatus, this difficulty had already been overcome for in later apparatus the aperture used approximated to the size of the mouth, or, in other cases, the nostrils. Further, the velocity of air entering the apertures approximated to that obtaining in ordinary breathing, although the intermittent action of breathing had not been reproduced.

One speaker had described the paper as alarmist in character and suggested that much rubbing down could be dispensed with if paint work was properly executed. True as the latter point might be, the problem before us was to deal with the risk of the painter as it existed, although no one was more anxious than the author to see the painting craft raised to its proper level in respect to craftsmanship.

The remarks of Captain Carter as to looking to America for salvation were made under a misapprehension for the firm mentioned by him was not responsible for the waterproof sandpaper with which the experiments had been made. He (Mr. Klein) was anxious to see waterproof sandpaper introduced, and if it could not be produced in this country, there was no reason why the product of any other country should not be used. He thought, however, that he had made it quite plain that waterproof sandpaper would be produced in this country at an early date. Further, it was said that damp rubbing down was merely side-tracking the Geneva Convention. This remark was also made under a misapprehension, for the Geneva Convention provided only for the prohibition of the use of white lead and sulphate of lead, and of all products containing these pigments in the internal painting of buildings, except where the use of white lead or sulphate of lead or products containing these pigments was considered necessary for railway stations or industrial establishments. This prohibition could not, therefore, be regarded as being entire even in respect to the internal painting of buildings. Further, in countries where the Convention was ratified, prohibition did not come into force until 1927. It was, however, laid down that following ratification, measures should be taken (not later than January 1st, 1924), wherever practicable, in order to prevent danger arising from dust caused by dry rubbing down and scraping of lead paints. The damp rubbing down method involving the use of waterproof sandpaper, satisfactorily met this requirement, and in these circumstances the suggestion of side-tracking was wholly unwarranted.

On the motion of the Chairman a vote of thanks was accorded to Mr. Klein for his interesting paper, and the meeting terminated.

OBITUARY.

HENRY CLEWS, LL.D., PH.D.—Dr. Henry Clews, whose death took place on January 31st, was elected a Fellow of the Royal Society of Arts in 1904. He was born in 1840, and on leaving school entered mercantile life at New York. After the panic of 1857 he organised the banking firm of Stout, Clews and Mason, which subsequently became known as Livermore, Clews and Company. On the outbreak of the Civil War he was appointed financial agent for the sale of bond issues to carry on the war. In 1877 he organised the firm of Henry Clews and Company, of which he remained the head until the time of his death. The firm was appointed by General Grant fiscal agent of the United States Government for all foreign nations; and Dr. Clews was adviser and agent in organising the new financial system of Japan. Apart from his professional activities he found time for much public and philanthropic work: he was President of the American Peace and Arbitration League, of the National Highways Protective

Association; a director of the American Civic Alliance, and of the Japan Peace Society; and Treasurer of the American Geographical Society, and of the Society for the Prevention of Cruelty to Animals. He was also the author of several works including "Twenty-eight Years in Wall Street" (1885); "The Wall Street Point of View" (1900); and "Fifty Years in Wall Street" (1908).

GERMAN MANUFACTURE OF FABRICS FROM COTTON-WASTE.

The principal German textile districts in which cotton-waste manufacturing is carried on are Bavaria, Wurtemburg, Baden, Rhineland, and Westphalia. Many mills turn out cotton-waste fabrics, however, working only part time on such yarns and fabrics. The total number of spindles employed in this industry is not definitely known, but the German Federal Bureau for the Cotton industry (Reichswirtschaftsstelle fuer Baumwolle) estimates the number of mills which work on cotton-waste as 100. It is also stated that 10 to 15 per cent. of the total cloth manufactured in Germany is made from cotton-waste.

According to a report by the United States Assistant Commercial Attaché at Berlin, while mule spindles are at present in more general use on cotton-waste, ring spindles seem to be more extensively used in replacements. Plain types of looms, chiefly the four-harness type, are in use; automatic or Jacquard looms are used only to a small extent. The condenser system is employed almost entirely for preparing the waste.

All sorts of cotton-waste materials are consumed by the mills, but linters, sweepings, rags, lap ends, clippings, sliver, and bobbin waste are most common. The principal products made from these wastes are light weight, coarse textiles, which are consumed chiefly by the peasant classes of Germany or exported to foreign countries with low foreign exchange rates. Other uses of cotton-waste in Germany are in the manufacture of cheap blankets, felt, cleaning rags, and machinery waste, and a rather large quantity is consumed by paper manufacturers in making paper roofing.

COPPER MINES IN THE BELGIAN CONGO.

The copper mines controlled by the Belgian Government are situated in the Katanga district, which holds a pre-eminent position in the world's copper industry, and where more than a hundred deposits of copper are worked. At Elisabethville, where the work extends over the Kambove and Star veins, there are seven smelting furnaces producing 40,000 tons of copper per annum. The Kambove vein extends from Elisabethville to Ruwe. The concession held by the company working the deposits is for all the veins and deposits of copper and tin of the Upper Katanga and is for a term expiring in 1990.

From a report by the United States Vice-Consul at Antwerp it appears that all the ore extracted from the mines is treated by the foundry at Lubumbashi, near Elisabethville, and is an oxidized ore, malachite being one of the forms most frequently met with in the Katanga. The ore smelted in blast furnaces (cooled externally by a circulation of water) gives raw copper with 96 to 97 per cent. of pure copper. To treat 100 tons of this ore 80 tons of limestone or iron ore and 36 tons of coke must be added in the blast furnace. The Lubumbashi foundry employs nearly 200 European workmen and 2,500 natives.

Another important centre is in the course of development at Kikasi, 150 kilometres north-east of Elisabethville, and connected by the principal lines to Kamantanda, near Kambove. Concentration works using the electro-chemical system, with a capacity of 4,000 tons per day, have been operating there since 1920.

TECHNICAL TRAINING FOR INDIAN STUDENTS.

The annual report of the Indian Students' Department, a branch of the High Commissioner's Office in London, shows that no difficulty has been found in securing admission to suitable Universities, Technical Colleges and similar institutions for Indian technical scholars sent to this country, but trade stagnation, etc., made it increasingly difficult to secure practical workshop or factory training—a handicap not confined to Indian students. The report continues:—"In other branches of industry, such as leather and paper making, we have come across instances of British firms who have frankly stated their unwillingness, for various reasons, to take Indian students for practical training. Such a policy on the part of home manufacturers is, as was emphasised in the previous report, much to be deplored, but it is hoped that the steps now being taken to induce British firms to adopt a more generous attitude, will eventually bring about a decided improvement. The High Commissioner has himself given careful consideration to the matter, and has decided that, other things being approximately equal, preference in the placing of Indian contracts for stores and material will be given to those firms who are prepared to take Indian technical students when asked to do so." The report gives the names of the firms, 11 in number, who, during the twelve-months ended on 31st March last, accepted Indian scholars and students for practical training. Indian students were also taken for "traffic training" by the London and North-Western, Great Eastern, Great Central, Midland, Lancashire and Yorkshire, and Furness Railways.

It is pointed out, however, that a student who adopts traffic training here to secure an appointment in India, without reasonable assurance of such an appointment, runs a great risk. There were 35 technical scholars under the charge of the Students' Department; 647 Indians were studying law at the various Inns of Court.

NORWEGIAN CARBIDE AND CYANAMIDE INDUSTRIES.

Norway has eight modern, well-equipped calcium carbide plants, three of them built during the war, with a total annual output capacity of about 265,000 tons. These plants have installed about 170,000 horse-power and in full operation employ about 3,000 men. According to a report by the United States Consul at Bergen, several of the plants are now completely closed down, and the others are operating with small or minimum force.

Commenting on this situation in a recent address, Mr. Ove Collet, a leading Norwegian electrochemical engineer, said that before the war the total world's production of calcium carbide was about 350,000 tons per year; that to-day Norway has factories with a capacity of nearly 80 per cent. of the pre-war world production, and that war-time optimism as to the future of carbide has proved to be without sound basis, especially so far as the production of cyanamides is concerned.

The single cyanamide factory in Norway, that at Odda in the Bergen district, with its annual capacity of 75,000 tons, has been closed down for more than a year, and it is extremely doubtful whether it, or the carbide factory at the same place, which counted upon delivering a large part of its product for the manufacture of cyanamides, will ever again be in operation—certainly not unless new uses for both carbide and cyanamides can be found.

GENERAL NOTES.

International Congress on Architectural Education.—The Council of the Royal Institute of British Architects have decided to hold an International Congress on Architectural Education in London in the autumn of 1924. The Congress will consist of special meetings for the purpose of considering the history, position and prospects of Architectural Education, with special reference to the following points:—*The revision of the methods and system of obtaining professional qualifications. The Sources of Study. The Use of Travel. Prizes and Awards of Honour. Preliminary Studies. Detailed Subjects.*—Draughtsmanship. Study of History. Practical Handwork. Professional Journals. Contact with Works. *Examinations.*—Standards. Relation to Practice. Paid Examiners. *Promotion of Post-graduate Studies.*—Relation to preliminary and general education. The subject of the Congress, important at all times to Architects, is more than ever important at the present day, in view of the vital changes which are being introduced into British Architectural Education by the Schools. It is hoped that a national and international exchange of ideas will lead to valuable future developments.

Vegetable Tallow Trade of China.—Exports of vegetable tallow from China total annually about 200,000 piculs (1 picul = 133⅓ pounds), most of which, before the war, was sent to the Netherlands, France and Germany. Since the war, however, the United States, Italy and Great Britain have become the chief buyers. The following figures quoted from the Chinese Maritime Customs show the exports of the commodity in China's trade from 1914 to 1920, the amounts being in piculs: 1914, 190,094; 1915, 181,482; 1916, 256,960; 1917, 151,385; 1918, 162,881; 1919, 164,544; 1920, 69,118. The home consumption is about equal to the foreign demand. Hankow controls 90 per cent. of the total export trade. According to information published by the Far Eastern Division of the U.S. Bureau of Foreign and Domestic Commerce, the producing districts are in the north-western part of Suifoo, Szechwan, in the hsiens on the borders of Hupeh-Szechwan, and Kweichow, and the north-western section of Hweichow, Anhwei. In China the tallow is used mostly in the manufacture of candles. Under the heading of vegetable tallow there are three kinds, namely, "Pie Yu" or skin tallow, obtained from the fat which adheres to the seeds; "Tse Yu," or seed tallow, obtained from the kernels of the seeds, and "Mu Yu," or wool tallow, a mixture of skin and seed tallow. The so-called Chinese vegetable tallow contains about 10 to 20 per cent. of wool tallow.

Tobacco Growing in Spain.—In order to foster the cultivation of tobacco in Spain, a central commission has been appointed to furnish scientific information to growers as to methods of culture, curing and handling, and to assume full control of tobacco production. It is estimated, says the United States Consul at Barcelona, that 2,470 acres will be planted in 1923, with an approximate yield of 3,500,000 pounds of varieties similar to Kentucky and Havana. The price which will be paid for cured leaf unmanufactured on delivery to the warehouse is as follows:—First grade, 2.50 pesetas per kilo; second grade, 2 pesetas per kilo; third grade, 1.50 pesetas per kilo; and fourth grade, 1 peseta per kilo. The Government representative and the Compania Arrendataria de Tobacos (Tobacco Monopoly) are authorised to appoint all experts necessary to aid the central commission.

The French Mirror Glass Industry.—At the outbreak of the World War, France possessed six factories engaged in the manufacture of mirror glass, situated in the following localities:—Chauny, Cirey, Aniche, Assevent-les-Mauberge, Boussois, and Montlucon. All these factories, with the exception of that at Montlucon, were in the war zone, and of these five factories the glassworks at Boussois, although heavily damaged, was the only establishment which escaped total destruction. It is reported, writes the United States Consul at Nancy, that the factory at Boussois, with its three ovens in operation, has almost attained its pre-war output. A thoroughly modern factory is under construction at Compiègne, near Paris, and reconstruction work at Cirey is progressing rapidly. It was expected that the output by the end of the year would equal that of the pre-war period. Competent authorities state that within a year or two France will have regained its former importance in this industry.

Hydro-Electric Power in Winnipeg.—An excellent account is contained in an illustrated pamphlet by Mr. J. G. Glassco, of the Winnipeg Hydro-electric System. The power house is situated at Point du Bois, on the Winnipeg River, 78 miles north-east of the City of Winnipeg. This river, with its tributary, the English River, has a drainage basin of 52,000 square miles. The principal storage basins are the Lake of the Woods, 1,500 square miles; Rainy Lake, 330 square miles, and Lac Seul, 340 square miles. A minimum flow of 20,000 sec. feet is assured. At the power house site the river falls over a series of rapids which in their natural state give a fall of 33 to 28 feet in a distance of about a quarter of a mile. By means of a dam a total head of 43 to 48 feet has been obtained, and a pondage area of seven square miles. The power house, a reinforced concrete structure 523 feet long, acts as a gravity dam at the end of the canal, which conveys the water to the power house. The number of units generated has risen from 38,704,220 in 1913 to 125,124,855 in 1921, and the number of customers has increased in the same time from 22,015 to 44,953.

Experiments with Maguey Fibre in Mexico.—The Industrial Experiment Laboratory of the Department of Industry, Commerce and Labour in Mexico, has been conducting experiments for the utilisation of the fibre of the maguey plant. The Laboratory's experiments, writes the United States Consul General at Mexico City, have been along biological lines, using bacteria for producing fermentation and disintegration of the maguey pulp. It has been found that the process of fermentation employed leaves the fibre stronger than when passed through the stripping machine, and the new process conserves the cuticle of the fibre, whereas the former machine process destroyed it.

Lead Pencil Industry of Japan.—Data regarding the lead-pencil industry of Japan have been obtained, by the United States Commercial Attaché at Tokio, from the Imperial Commercial Museum of the Department of Agriculture, showing that in 1918 there were exported 1,292,903 gross; in 1919, 623,037 gross, and in 1920, 248,082 gross. During the years 1916, 1917, 1918 and 1919, the total output of lead pencils in the Japanese Empire was 9,868,000 gross. There are 117 pencil factories in the country, employing 2,171 workmen. Tokio alone has 80 pencil factories, other important centres being Osaka, Hiroshima, Mie and Wakayama.

Tanning of Cabrogoya Skins in Ceylon.—The tanning and exportation of cabrogoya skins from Ceylon is now being undertaken on a commercial scale for the first time, according to a report by the United States Consul at Colombo. The cabrogoya (*Varanus salvator*) is a species of lizard, ranging from 3 to 4½ feet in length. The leather is finely marked and has unusual wearing qualities. It is used in the manufacture of women's shoes. An average skin contains leather enough for the manufacture of two pairs of shoes.

Asbestos Deposits of Western Australia.—Deposits of asbestos are said to exist in many parts of the State of Western Australia, the best being found in the Pilbarra district, about 600 miles north of Perth, according to the United States Consul at Adelaide. Both the quantity and the quality of the product found vary considerably and it is rare that any mine yields more than a few hundredweight a month. Prospects for the industry, however, have been sufficiently promising for a Sydney firm to establish asbestos works outside of Perth for the manufacture of asbestos sheets, roofing tiles, and other construction utilities.

Uranium Protoxide in Czecho-Slovakia.—Oxide of black blende, or pitch ore, otherwise known as protoxide of uranium, is one of the valuable minerals obtained at the State mines of Jachymov in Western Bohemia, according to a report by the United States Consul at Prague. This mineral is used in the preparation of uranium colours and radium. As the Czecho-Slovak Government has a monopoly of the production of radium and other precious minerals within the republic, a special permit is required from the Ministry of Public Works for the purchase of protoxide of uranium and other valuable ores and minerals.

MEETINGS OF THE SOCIETY

Ordinary Meetings.

Wednesday evenings, at 8 p.m. :—

FEBRUARY 28.—PROFESSOR W. E. S. TURNER, D.Sc., Head of Department of Glass Technology, The University, Sheffield, "Heat Resisting Glasses." THE HON. SIR CHARLES A. PARSONS, K.C.B., LL.D., D.Sc., F.R.S., will preside.

MARCH 7.—EDWARD PERCY STEBBING, M.A., F.L.S., Professor of Forestry, University of Edinburgh, "The Forests of Russia." THE RIGHT HON. LORD CLINTON, Forestry Commissioner, will preside.

MARCH 14.—SIR WILLIAM WARRENDER MACKENZIE, K.B.E., K.C., President of the Industrial Court, "Industrial Arbitration." LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, will preside.

Indian Section.

Friday afternoons.

APRIL 6, at 4 p.m.—GEOFFREY ROTHE CLARKE, C.S.I., O.B.E., I.C.S., Director-General Posts and Telegraphs, India, "Postal and Telegraph Work in India." LORD MONTAGU OF BEAULIEU, K.C.I.E., C.S.I., will preside.

June 1, at 4.30 p.m.—AUSTIN KENDALL, I.C.S., rtd., "The Indian Section of the British Empire Exhibition, 1924."

JUNE 15, at 4.30 p.m.—SIR JOHN H. MARSHALL, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture).

Dominions and Colonies Section.

Tuesday afternoon at 4.30 o'clock.

MARCH 6.—Major E. A. Belcher, C.B.E., Assistant General Manager, British Empire Exhibition, "The Dominion and Colonial Sections of the British Empire Exhibition, 1924." THE RT. HON. L. S. AMERY, M.P., will preside.

Dominions and Colonies and Indian Sections. (Joint Meetings).

Tuesday or Friday afternoons at 4.30 o'clock.

MARCH 16.—Lieut.-Col. SIR LEONARD ROGERS, C.I.E., F.R.S., F.R.C.P., F.R.C.S., Thysician and Lecturer, London School of Propical Medicine, · "Recent Advances towards the Solution of the Leprosy Problem."

APRIL 20.—SIR RICHARD A. S. REDMAYNE, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S., "The Base Metal Resources of the British Empire."

MAY 1.—L. GUY RADCLIFFE, M.Sc. (Tech.), F.I.C., "The Essential Oils of the British Empire."

Dates to be hereafter announced:

WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Recent Developments in Surface Combustion."

MAURICE DRAKE, "The Development of Mediæval Technique in Stained Glass Windows."

EDWARD PARNELL, "The Resources and Trade of Sarawak."

Cantor Lectures.

Monday evenings, at 8 o'clock.

J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards, "Length Measurement." Three Lectures. March 5, 12, 19.

E. KILBURN SCOTT, Assoc.M.Inst.C.E., M.I.E.E. "The Fixation of Nitrogen." Three Lectures. April 9, 16, 23.

Howard Lectures.

Monday evenings at 8 o'clock.

STANLEY S. COOK, "Recent Improvement in Steam Turbines." Three Lectures. April 30, May 7, 14.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK

MONDAY, FEBRUARY 26 .. Geographical Society, 135, New Bond Street, W., 8.30 p.m. Lieut.-Col. T. T. Behrens, "The Brenner Pass Boundary and Italy's New Province."

Farmers' Club, at the Surveyors' Institution, 12, Gt. George St., S.W., 4 p.m. Sir A. D. Hall, "Can Silage be Substituted for Roots?"

Victoria Institute, Central Buildings, Westminster, S.W., 4.30 p.m. Dr. A. T. Schofield, "The Forces behind Spiritism."

Textile Institute (London Section), Mr. E. B. Fry, "Yarn Production (mainly Wool)"

Architectural Association, 34, Bedford Square, W.C., 7.30 p.m. Mr. G. Frankau, "Architecture and Literature."

Mechanical Engineers, Institution of (Graduates' Section), 7 p.m. Prof. E. G. Coker, "Photo-Elastimetric Researches on Mechanical Engineering Problems."

University of London, at King's College, Strand, W.C., 5.30 p.m. Rev. C. F. Rogers, "Ecclesiastical Music" (Lecture IV.) 5.30 p.m., Dr. W. Brown, "Psychology and Psychotherapy" (Lecture II.) 5.30 p.m., Prof. R. Dyboski, "Poland." (Lecture VI.)

At the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C., 5.15 p.m. Prof. M. Walker, "The Control of the Speed and Power Factor of Induction Motors." (Lecture II.)

TUESDAY, FEBRUARY 27 .. Massage and Medical Gymnastics, Society of, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 6 p.m. Dr. J. Mennell, "Manipulations of Bone-Setting & Osteopathy."

Colonial Institute, Hotel Victoria, Northumberland Avenue, W.C., 4 p.m.

Royal Institution, Albemarle Street, W., 3 p.m. Sir Arthur E. Shipley, "Life and its Rhythms." (Lecture I.)

Marine Engineers, Institute of, 85, The Minories, E., 6.30 p.m. Eng.-Comdr. R. Beeman, "Auxiliary Machinery."

Photographic Society, 35, Russell Square, W.C., 7 p.m. Mr. R. Chislett, "Bird Life in the North Isles of Shetland."

University of London, University College Gower Street, W.C., 5 p.m. Dr. W. B. Brierley, "Soil Fungi—the occurrence of Fungi in the Soil." 5.30 p.m., Mr. J. H. Helweg, "Contemporary Danish Literature." (Lecture IV.) 5.30 p.m., Mr. N. H. Baynes, "The Roman Empire in the IV. Century." (Lecture IV.) At King's College, Strand, W.C., 5.30 p.m. Prof. H. W. Carr, "Physical Causality and Modern Science" (Lecture II.) 5.30 p.m. Sir Bernard Pares, "Contemporary Russia from 1861." (Lecture VI.) 5.30 p.m., Mr. A. J. Toynbee, 'The Expansion of Europe Overland: the Route of the Steppes." (Lecture II.) At the London School of Economics, Houghton Street, Aldwych, W.C., 5 p.m. Sir Josiah Stamp, "Statistics, before, during and after the War: Income and Wages."

WEDNESDAY, FEBRUARY 28 .. Geological Society, Burlington House, Piccadilly, W., 5.30 p.m. Mr. S. H. Warren: (a), "The Late Glacial Stage of the Lea Valley (Third Report); (b), "The Elephas-Antiquus Bed of Clacton-on-Sea (Essex), and its Flora and Fauna."

United Service Institution, Whitehall, S.W., 3 p.m. Rear-Admiral H. W. Richmond, "Co-operation."

Industrial League and Council, Caxton Hall, Westminster, S.W., 7.30 p.m. Mr. H. G. Williams, "Fundamental Causes of Unemployment."

Literature, Royal Society of, 2, Bloomsbury Square, W.C., 5 p.m.

Public Health, Royal Institute of, 37, Russell Square, W.C., 4 p.m. Mr. E. R. T. Clarkson, "Note on Venereal Clinics—their Function and Organisation."

University of London, University College, Gower Street, W.C., 3 p.m. Prof. E. G. Gardner, "Dante in his Works." (Lecture III.) 5.30 p.m., Mr. I. C. Grøndahl "The World of Wergeland." (Lecture IV.) 5 p.m., Mr. P. Leon, "The Theory of Beauty." (Lecture III.) 5.30 p.m., Mr. G. H. Palmer, "Manuscript Influence on the Early Printed Book." At King's College, Strand, W.C., 5.30 p.m. Principal L. P. Jacks, "The Limitations of Natural Science."

At the London School of Economics, Houghton Street, Aldwych, W.C., 5 p.m. Professor G. Wallas, "The Competition of the Sexes for Employment."

THURSDAY, MARCH 1 .. Aeronautical Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.30 p.m. Major F. M. Green, "Helicopters."

Royal Society, Burlington House, Piccadilly, W., 4.30 p.m.

Linnean Society, Burlington House, Piccadilly, W., 5 p.m.

Chemical Society, Burlington House, Piccadilly, W., 8 p.m. (1) N. V. Sidgwick, "Co-ordination Compounds and the Bohr Atom." (2) W. H. Gray, "Silver Salvarsan."

British Architects, Royal Institute of, 9, Conduit Street, W., 5 p.m. Sir Ryland Adkins, "Architecture and the Countryside in Layman's Questions."

Auctioneers' and Estate Agents' Institute, 34, Russell Square, W.C., 6.30 p.m. Mr. H. M. Rogers, "The Making of a Connoisseur." (Part 2.)

Royal Institution, Albemarle Street, W., 3 p.m. Mr. T. Stevens, "Water Power of the Empire." (Lecture I.)

Mechanical Engineers, Institution of (Midland Branch), The University, Birmingham, 7.30 p.m. Mr. R. D. Summerfield, "Inspection of Engineering Material."

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C., 6 p.m. Messrs. S. W. Melsom and E. Fawssett, "Permisible Loading of British Standard Paper Insulated Electric Cables."

Child Study Society, at the Sanitary Institute, 90, Buckingham Palace-road, S.W., 6 p.m. Professor L. Hill, "The Sun and Open Air School."

Camera Club, 17, John Street, Adelphi, W.C. 8.15 p.m. Mr. G. B. Clifton, "My Method of Making Bromoil Prints."

Dyers and Colourists, Society of (West Riding Section), Bradford, 7.15 p.m. Mr. J. I. M. Jones, "The Development of Fast Dyes."

University of London, University College, Gower Street, W.C., 5 p.m. Dr. W. B. Brierley, "Soil Fungi — the Life of Fungi in the Soil." 5.30 p.m., Mr. I. Biorkhagen, "Swedish Literature in the XVIII. Century." (Lecture V.) 5.15 p.m. Mr. J. E. G. De Montmorency, "Distribution of Customary Law in England and France." At King's College, Strand, W.C., 5.30 p.m., Mr. F. Sobienowski, "Post War Poetry in Poland." At the London Hospital Medical College, Mile End, E., 4.30 p.m. Mr W. A. M. Smart, "The Mathematical Basis of Physiological Problems." (Lecture VII.) At the London School of Economics, Houghton Street, Aldwych, W.C., 6 p.m. Sir William Vincent, "Political Developments in India, from 1920 to 1922." (Lecture I.)

FRIDAY, MARCH 2 .. Royal Institution, Albemarle Street, W., 9 p.m. Dr. G. C. Simpson, "The Water in the Atmosphere."

Mechanical Engineers, Institution of (Yorkshire Branch), Philosophical Hall, Park Row, Leeds, 7.30 p.m.

Philological Society, University College, Gower Street, W.C., 5.30 p.m. Mr. C. T. Onions, "Dictionary Evening."

Sanitary Institute, Town Hall, Sheffield, 4.30 p.m. (1), Mr. J. Evans, "Extraneous Matters in Food; (2), Prof. E. Mellanby, "The Prevention of Disease by Feeding."

Engineers, Junior Institution of, 89, Victoria Street, S.W., 7.30 p.m. Mr. C. Saxton, "Glass Forming Machines."

University of London, University College, Gower Street, W.C., 5.15 p.m. Mr. W. de la Mare, "Modern Poetry." At King's College, Strand, W.C., 5.30 p.m. Mr. C. E. M. Joad, "The Case for Pluralism." (Lecture I.) 5.30 p.m. Dr. R. W. Seton-Watson, "Serbia and the Jugo-Slav Movement." (Lecture VII.)

SATURDAY, MARCH 3 .. Royal Institution, Albemarle Street, W., 3 p.m. Sir Ernest Rutherford, "Atomic Projectiles and their Properties." (Lecture III.)

London County Council, at the Horniman Museum, Forest Hill, S.E., 3.30 p.m. Miss M. A. Murray, "Legends of the Gods of Ancient Egypt."

Journal of the Royal Society of Arts.

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FRIDAY, MARCH 2, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

NOTICES.

NEXT WEEK

MONDAY, MARCH 5th, at 8 p.m. (Cantor Lecture). J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards, "Length Measurement." (Lecture I.)

TUESDAY, MARCH 6th, at 4.30 p.m. (Dominions and Colonies Section.) MAJOR E. A. BELCHER, C.B.E., Assistant General Manager, British Empire Exhibition, "The Dominion and Colonial Sections of the British Empire Exhibition, 1924." THE RT. HON. L. S. AMERY, M.P., will preside.

WEDNESDAY, MARCH 7th, at 8 p.m. (Ordinary Meeting.)—EDWARD PERCY STEBBING, M.A., F.L.S., Professor of Forestry, University of Edinburgh, "The Forests of Russia." THE RIGHT HON. LORD CLINTON, Forestry Commissioner, will preside.

TWELFTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 21st, 1923; SIR RICHARD D. MUIR, Senior Treasury Counsel, Central Criminal Court, in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Ginsburg, Samuel Rowland, Mem. Am. Soc.C.E., Santo Domingo, W. Indies.
Lahary, R. S. D., Delhi, India.
Lednum, Edmund Townsend, Denver, Colorado, U.S.A.
Matthews, E., Bombay, India.

The following candidates were duly elected Fellows of the Society:

Crawford, Lieut.-Colonel W. L., D.S.O., Saklaspur, Hassan, India.
Ely, Professor John Andrews, Shanghai, China.
Macdonald, Mrs. L. M. Montgomery, Leaskdale, Ontario, Canada.
Morse, Arthur Hyatt, A.M.I.E.E., Montreal, Canada.
Moyer, Professor James Ambrose, Boston, U.S.A.
Smith, John Frederick, Headingley, Leeds.
Smythe, Albert Ernest Stafford, Toronto, Canada.

A paper on "Handwriting and its Value as Evidence," was read by MR. C. AINSWORTH MITCHELL, M.A., F.I.C.

The paper and discussion will be published in a subsequent number of the *Journal.*

RE-OPENING OF THE LIBRARY.

The Library, which has been entirely renovated and re-furnished, is now open to Fellows daily from 10 a.m. to 6 p.m. (Saturdays 10 a.m. to 1 p.m.)

Fellows can obtain tea between 4 and 6 p.m. at moderate prices.

SETS OF THE JOURNAL.

The undermentioned short sets of bound volumes of the *Journal* have recently been returned to the Society, and they will be presented to any Library which will purchase the remaining volumes required to bring the set up to date.

1.—Vols. 9-45 (1861-1897); the remaining Vols. 46-70 can be obtained for £9.
2.—Vols. 25-42 (1877-1894); the remaining Vols. 43-70 can be obtained for £10.

THE SOCIETY'S HOUSE.

The lease granted to the Society by the Brothers Adam in 1775 expired, after certain renewals, in 1904. A temporary arrangement was made which lasted till 1920, when the Council received notice that it would be terminated in March, 1922. A Premises Committee was thereupon appointed to consider the question of raising a fund to purchase the Society's House. It consisted of the Chairman of the Council (Sir Henry Trueman Wood), Sir Charles Allom, Lord Blyth, Sir Dugald Clerk, K.B.E., F.R.S.,

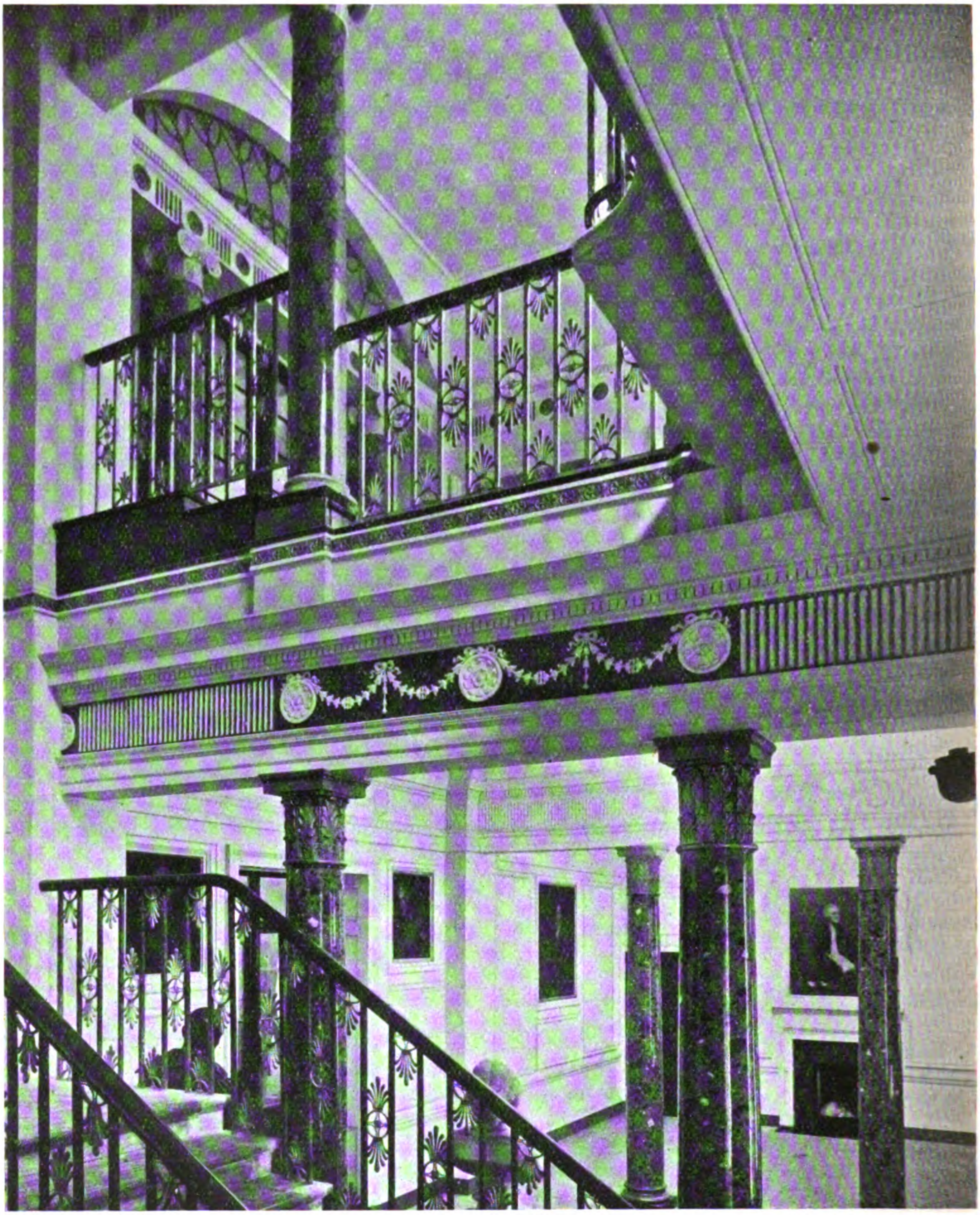


Fig. 1.—Entrance Hall and Staircase.

Mr. John Slater, F.R.I.B.A., and Mr. Alan A. Campbell Swinton, F.R.S.

Mr. Campbell Swinton was elected Chairman of the Committee; he has throughout taken the warmest interest in the acquisition and renovation of the House, and the fact that the Society is now the owner of its valuable premises is due in a large measure to his initiation and energy.

After some preliminary enquiries, Mr. Campbell Swinton was able to report to the Council that he had received promises of subscriptions as follows:—

	£
The Hon. Sir Charles Parsons, K.C.B., F.R.S.	2,500
Lord Bearsted	1,000
Sir Dugald Clerk, K.B.E., F.R.S. ..	1,000
The Earl of Iveagh, K.P., G.C.V.O.	1,000
Lord Leverhulme	1,000
Alan A. Campbell Swinton, Esq., F.R.S.	1,000

Shortly after this, in July, 1921, the Secretary reported to the Council that a donor, who desired to remain anonymous, had contributed £30,000. It was then decided to issue a general appeal to the Fellows, inviting them to make up the sum already promised to £50,000, the amount required for the purchase of the site and building, and for the cost of such repairs as were considered necessary. The appeal met with a fairly satisfactory result, a number of Fellows having made very generous contributions. Seven lists of subscriptions have been published in the *Journal*,* and the total now is nearly £43,000. The actual purchase of the premises was effected in March, 1922.

As soon as it was seen that there was a reasonable prospect of securing the House, the Premises Committee met frequently to consider what steps should be taken to renovate and decorate the building. In this connection Mr. John Slater rendered great service to the Society, for which he received the cordial thanks of the Council. It was decided that the renovations should be started as soon as possible after the close of the session, and in February, 1922, Mr. Arthur Bolton, F.R.I.B.A., Curator of the Soane Museum, was appointed as architect, his recently published book "The Architecture of Robert and James Adam," having established his reputation as an authority on Adam work. The Committee held various meetings with Mr. Bolton: at one of these Sir Aston Webb, P.R.A., was present, and he made certain valuable suggestions which were incorporated in the final plans.

The work, which was started about the middle of July, is now complete, and as many Fellows have not yet had an opportunity of visiting the renovated house, it was thought that some account of it would be interesting, especially to those who have contributed to the Building Fund. The accompanying illustrations are reproduced from the *Builder*, by permission of the Editor, and the following particulars are also taken from an article which appeared in that paper.

The object of the restoration has been as far as modern conditions allowed, to bring back the interior to its original state, while at the same time making certain alterations imperatively demanded by the present work of the Society.

A new entrance hall has been formed by the removal of two cross walls on the ground floor, for which columns of Adam character have been substituted. The wall of the ante-room on the first floor has similarly been taken away, so that this large space might be included in the staircase. The effect of a miniature grand staircase has been further secured by the demolition of the upper flights, no longer required to reach the second floor, a new room being thus obtained at that level. Originally there was a small model room along the second-floor front, to which there was public access, but this had been long ago disused, the upper floor being required for the clerical and other administrative work of the Society. The walls of the staircase, thus converted, have been panelled, framing in the two large portraits of Queen Victoria and the Prince Consort painted for the Great Room about 1860. The stone steps and landings, inlaid many years ago with glass mosaic by Messrs. Powell, have been left, but the plain iron balustrade has been ornamented with Adam anthemiums of cast lead, made and fixed by Messrs. Elsley. The actual entrance to the Great Room from the ante-room had been altered from the original simple doorway to a great gap, closed by sliding panels. This entrance has now been treated in an architectural manner, as the photograph will show. The northern third of the ante-room floor has now been raised in three steps, and this new level carried

*See *Journals* of December 2nd, 1921, January 13th, February 24th, May 5th, July 14th, November 17th, 1922, and February 9th, 1923.

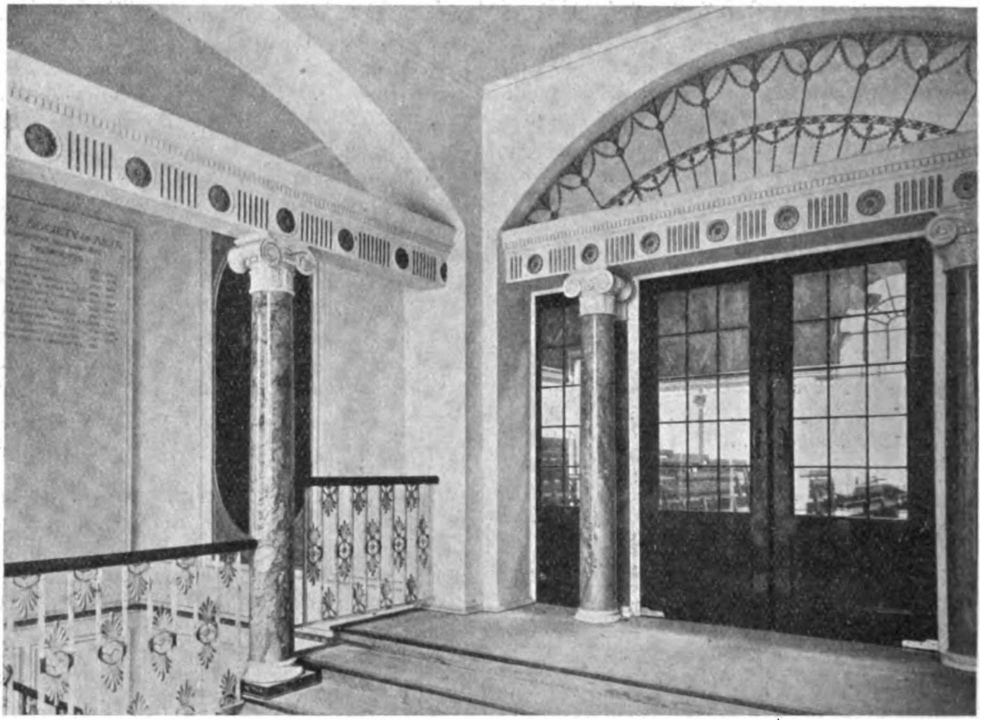


FIG. 2.—Entrance to Lecture Hall.

through, which, with a descent and ascent, gives the required graded elevation for the new seating.

The effect aimed at was that of giving the real size of the great pictures, which are 42 and 36 ft. long by 12 ft. high. The two original Adam mantelpieces of marble have been reinstated in the Library below. In their place two recesses have been formed in the thick walls, one for the lantern and its requirements, and the other for a panic exit, and cupboards for the extensive electrical contrivances necessary for the scientific and other lectures. Everything is thus fixed, as far as possible, out of sight behind the panelling. The two portraits of the first and second Presidents of the Society —Viscount Folkestone, by Thos. Gainsborough, R.A., and Lord Romney, by Sir Joshua Reynolds, P.R.A.—have been replaced in their original positions. Ultimately their coats of arms in relief will be restored in the panels over them.

The subdivisions of the main cove, introduced in 1840, were easily removed, as the plaster was intact behind them; the rather trivial colour decoration of that period has also been obliterated. The original Adam eliptical skylight was altered in 1815, and the present dome-like opening was formed in 1840. This has merely been simplified by the removal of mouldings, so that the original plain effect of the ceiling has been as far as possible restored. To meet the requirements of the lantern use of the room a velarium has been devised by the architect, actuated by a small electric motor, so that the room can be instantly darkened by touching a button.

The Library below was seriously cut up in 1840; the four original Adam columns were then replaced by curious cast-iron showcases, which supported the floor. The original dowel holes of the columns were found, and the four isolated columns have now been restored from an indication given by a slight woodcut view of this room in the *Illustrated London News* of about 1840.

The old centre window northwards has been reinstated, and two other windows opened up, and the walls are now lined with new bookcases, on which are placed a collection of busts, found on the premises of the Society. Below the Library a new book store, accessible by a private staircase for the librarian, has been created, and in the sub-basement the heating and hot-water supply has been installed, with an outlet to the Durham-hill roadway.

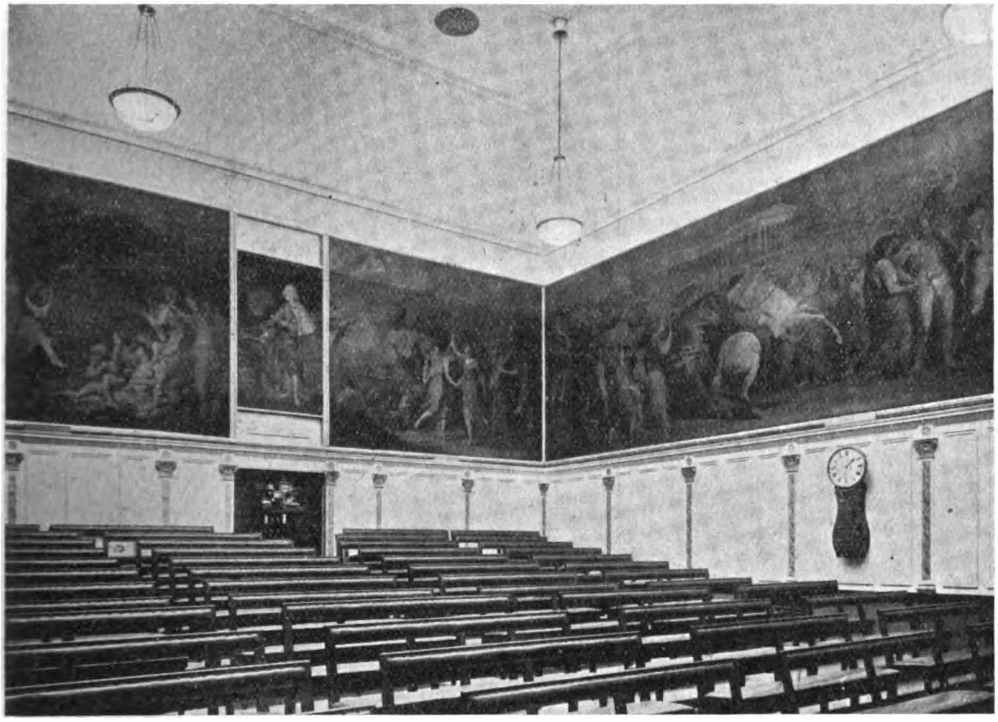
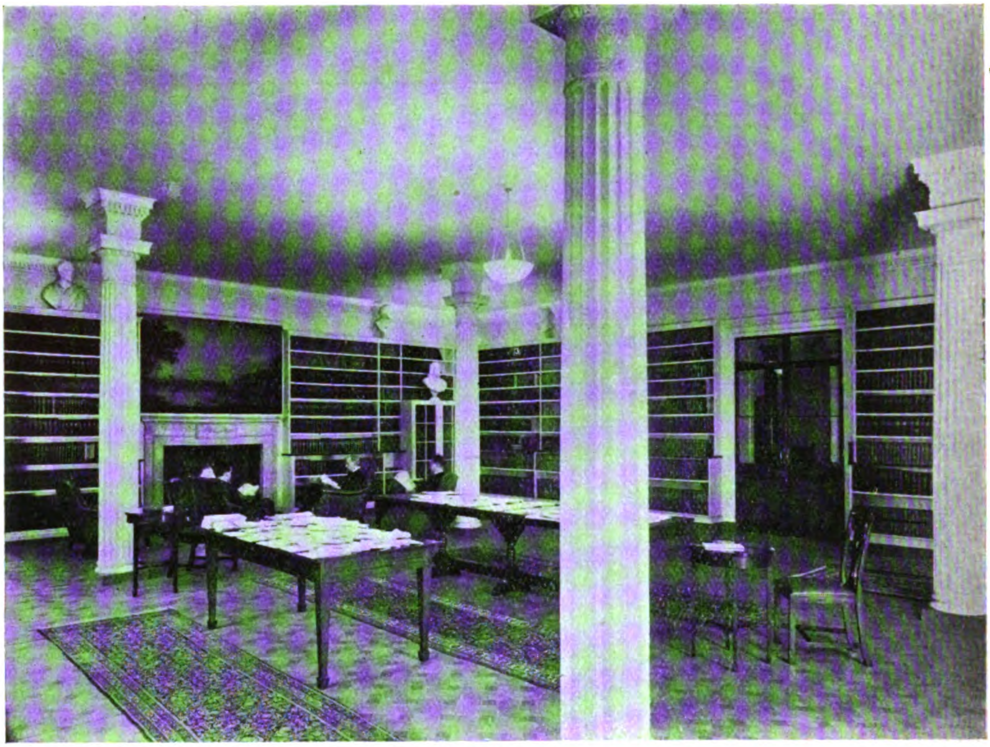


Fig. 3.—The Lecture Hall: West and North Walls.

Fig. 4.—The Lecture Hall: East and South Walls.



The Library.

The Library has now been comfortably furnished, and is open daily from 10 a.m. to 6 p.m. (Saturdays, 10 a.m. to 1 p.m.), to Fellows, who can procure tea from 4 to 6 p.m., at moderate charges.

The Library contains a large collection of Proceedings and Transactions of kindred Societies, and it is hoped that Fellows will make use of these for purposes of reference. There are complete sets of the Proceedings of the Institutions mentioned below, and long sequences of the reports of other Societies:—

British Association.
Chemical Society.
Institute of Bankers.
Institution of Civil Engineers.
,, ,, Electrical Engineers.
,, ,, Mechanical Engineers.
,, ,, Naval Architects.
Iron and Steel Institute.
Physical Society.
Royal Agricultural Society.
Royal Colonial Institute.
Royal Geographical Society.
Royal Meteorological Society.
Royal Photographic Society.
Royal Sanitary Institute.
Royal Society.
Royal Statistical Society.
Royal United Service Institution.

There are also complete sets of such periodicals as the *Builder*, *Chemical News*, *Engineer*, *Engineering*, *Nature*. *Quarterly Review*, etc. The Society further possesses the most complete collection extant of catalogues and reports of International and other Exhibitions. The collection of general works is not very large, and the Society would welcome gifts of recent works and text books on Arts, Manufactures and Applied Science.

The fireplace in the new hall is an original carved wood Adam mantel removed from a back room long utilised for a lavatory. The pictures now framed in the wall panelling of the new hall are portraits that belonged to the Society, and possess a considerable interest.

The old heating was on Perkins's original high-pressure system, and this has been reconstructed, the furnace being rebuilt in the sub-basement. The ventilation was very curious; a separate furnace existed to heat coils in a shaft, in connection with very large trunks in the roof over the Great Room. The north wall of the Great Room had been covered with coils of pipes, concealed by a false wall of thin boarding, and air, admitted by some disfiguring external tubes, was supposed to come out warmed through a

continuous grating, just below the great picture on this wall. It was all choked up with London dirt, and must have been inoperative for years past. In place of this old system recesses have now been formed in the dado for pipe coils acting as radiators, and a cold-air duct below a hot-air chamber heated by twelve pipes has been formed beneath the raised staging, with fifteen outlets through the risers. Motive power, in addition to the natural rise of the hot air, is provided by a 24in. electric motor-fan fixed in the old upcast shaft on the roof, and the result appears to be very satisfactory. The new lighting in the Great Room is by four Italian alabaster bowls, and is equal to 2,000 candle-power, the same amount that had been given by four bulky chandeliers which had been converted from gas. The gradual transition from lamps to gas, and so to early forms of electric light, is described in Sir Henry Trueman Wood's "History of the Royal Society of Arts."

The whole work has been done in about four months. The architect is Mr. Arthur Bolton, F.R.I.B.A., 10, Lincoln's Inn Fields; quantity surveyors, Messrs. Widnell & Trollope, Broadway Court, S.W. 1.; general contractors, Messrs. Trollope & Colls, Grosvenor Road ; electric lighting, ventilating fan, and motor to raise velarium, Messrs. Edmundson's Electricity Corporation, Ltd., heating, Messrs. Baker, Son & Perkins ; library furniture, Messrs. Hampton & Sons, Ltd. ; terrazzo marble floor, Messrs. Burke & Co. ; radiator grilles and balustrade ornaments, Messrs. T. Elsley & Co. ; decorative plaster work, Mr. Laurence Turner ; grates, Messrs. T. Elsley & Co. and Messrs. Robbins, of Dudley ; the new seating, bookcases, etc., Messrs. Trollope & Colls ; hardware, Messrs. Comyn Ching ; constructional steelwork, Messrs. Matthew T. Shaw, of Millwall ; hot-water supply, Mr. Thomas Potterton.

PROCEEDINGS OF THE SOCIETY.

EIGHTH ORDINARY MEETING.

WEDNESDAY, JANUARY 24TH, 1923.

SIR FRANCIS GRANT OGILVIE, C.B., LL.D. (Chairman of the Geological Survey Board), in the Chair.

THE CHAIRMAN, at the outset, said that he deeply regretted that the two principal figures whom it had been hoped to see on that occasion were absent. Mr. Campbell Swinton, who was to have taken the Chair, was unfortunately ill, and so, most unfortunately, was Sir William Bragg. The meeting was fortunate, however, in the presence of Mr. G. Shearer, who had been Sir William Bragg's right-hand in a very large proportion of his investigations. Mr. Shearer had been provided with what Sir William Bragg intended to say, and he was sure that he would expound the subject very satisfactorily.

MR. SHEARER then delivered the

SIXTH TRUEMAN WOOD LECTURE

"NEW METHODS OF CRYSTAL ANALYSIS AND THEIR BEARING ON PURE AND APPLIED SCIENCE."

By SIR WILLIAM HENRY BRAGG, K.B.E., D.Sc., F.R.S.,

Quain Professor of Physics, University of London.

It is one of the most fascinating of all studies to trace back the properties of the substances that we see round about us to the manner and the details of their underlying structure. There are in the world, or, indeed, the universe, a certain number of different kinds of the atoms of which all things are made. We know of rather more than ninety in all. The science of radioactivity has brought to our notice atoms distinguished by special powers of emitting radiations, but the list is not really increased thereby. Everything we see round about us, or know of, when perhaps we cannot see, is built up by joining together these atoms in various ways : and all the properties of substances, their infinite complications, powers, and beauties are associated with the properties of the atoms even before construction is begun. It is surely no wonder that we try to find out how this is done.

Chemistry itself has its origin in this quest. One of its early successes was the explanation—incomplete, no doubt, but then no explanation is ever really complete—of the part played by oxygen in the act of burning or rusting. As chemistry has grown to its present magnitude all its findings have related to the part played by this or that atom or combination of atoms in determining the properties of the various substances. The methods of chemistry are founded on studies of the behaviour of crowds. The smallest portion of any substance handled in the laboratory contains billions of atoms ; and the properties of the individual are

inferred from the treatment of gross aggregates. The chemist mixes together two liquids in certain proportions, observes, tests and weighs the results; and he infers that atoms already grouped in certain combinations are ready to change to fresh groupings. From his weighings he finds the proportions in which the atoms break with one another and recombine. He observes and measures their readiness to change partners. Sometimes the exchange is so rapid that energy is liberated with explosive violence. Sometimes it is so slow that it must be hurried, either by the application of warmth or by other means, quaintest of which is the action of a catalyst, the third body which promotes a new grouping without being finally concerned in it; as the chaperone of bygone days effected the introduction between two people anxious to meet each other and then effaced herself.

The science of radioactivity takes up the study of the atom in a totally different way. It finds that sometimes atoms are endowed with movement so rapid that the individual has enough energy to make its own mark. In the spinthariscope of 25 years ago Sir William Crookes showed the separate and visible flashes which were made when a succession of helium atoms, shot out from radium, struck a phosphorescent screen. Each impact made its little flash of light, just as when a pebble is dropped at night into a phosphorescent sea. This is a typical experiment belonging to the science of radioactivity, typical in that it deals with the individual and not with the crowd. In this science there is very little concern with the combinations of atoms. It leads more to a study of the nature of the internal structure of the atom: that is why, if we wish to understand the atom's inner mechanism, we turn to the work which J. J. Thomson, Rutherford, Aston and others are doing. The new methods of which I wish to speak to you to-night deal with the question from yet another aspect entirely different from the others. They are based on the recognition of the properties of crystals on the one hand and of X-rays on the other. Let us consider the crystal first.

A crystal that has grown without disturbance presents surfaces of brilliant polish which make with each other angles of characteristic and invariable magnitude. Sometimes one face grows abnormally as compared to others on account, it may be, of some disposing cause in the circumstances under which the crystal was found, but in crystals of the same substance the angles between corresponding faces are always exactly the same. There are not, usually, many different kinds of faces on a crystal. Often on careful examination it is found that there are not more than three or four. If we examine specimens of the same crystal which seem at first sight to differ in form, we find that the difference is nothing more than an unequal development of the various types of face. An outward presentment, so simple as this, must imply a like simplicity in internal design. There must be a unit of pattern which contains but few atoms and, repeated again and again through space, makes up the whole crystal. The idea has long been familiar to the crystallographer, but he could not push the corresponding interpretation to its limits: he had no clue to guide him, no methods of examining the actual details of the design. The reason of the failure is not difficult to understand: the details were too fine to be distinguished under the most powerful microscope. Nor is this a mere question of a lack of technical skill which might be removed at some future time. It will never be possible to see the arrangements of atoms in a crystal.

When we say that we see any particular thing, what we really do is to observe some change which the thing has made in the light waves which reach our eyes after they have been reflected or scattered or in some other way affected by the thing that is seen. This means that the thing itself must be comparable in size with the wave length of light. We could not expect to gather from the behaviour of a breaker as it rushed up the beach information as to the size and form of the individual grains of sand over which it had passed. We might expect, however, to be able to gather information as to the extent of a reef from observation of the degree to which it had stilled the waves that traversed it before they reached the shore. Now the diameter of an atom is quite a thousand times less than the length of the light waves which affect our eyes. Consequently it is out of the question that we should ever see it in the sense that we can see small objects even under the microscope. A very simple way to realise this point is to consider that the atoms form part of the very lenses of the microscope; and, if we tried to increase our power of microscopic vision by re-designing the optical

arrangement the lenses would have become, so to speak, granular and have lost their optical properties long before we were able to "see atoms by their aid." The fact is that light waves are adapted for ordinary seeing and that by the microscope we have stretched their proper range some thousands of times. Nothing that we can ever do with ordinary light will give us the magnification of a hundred million times, which is what we require if we are to study the atoms themselves. We want a new sort of light of immensely finer quality than ordinary light; and we have been fortunate enough to find this in the X-rays. X-rays are simply a form of light the wave length of which is ten thousand times shorter than that of the light with which we see in the normal way.

There is one more point to be made clear before we can realise how the combination of X-rays and the crystal have opened up a new vista. Although the X-ray is so fine in structure that it can really be affected by the individual atom, the magnitude of that effect is too small to be of any use: it is here that the crystal helps us. We remember that there is in the crystal a perfectly regular repetition of some simple pattern or combination of atoms. When X-rays sweep over them, whatever effect one of the units has, all its fellows have also; and so on the whole there is a combined action big enough in its results to be detected by instruments designed for the purpose. In somewhat the same way, to take an example, each tiny furrow on a piece of mother of pearl is of the right order of width to have an effect on the light which is reflected by the whole piece, but the magnitude of one such effect is not enough to make an impression on our eyes. But on the surface of the pearl there are many thousands of such furrows very like one another and running more or less in the same direction, and what one furrow does the others do also. It is this combined or multiplied action which so affects the light as to give the beautiful play of colour associated with mother of pearl.

Now we have all the factors essential to the new methods: the X-rays for fineness of vision and the crystal for combination in the action of the atoms upon the X-rays. It is not necessary now to go into further details, it is only needful to realise that there is an instrument called the X-ray spectrometer in which the reaction between the X-rays and the atomic arrangements enables us to study the form and size and disposition or structure of the atomic patterns of the crystal.

Every crystal is in a way a long avenue down which we can look and see at the far end of it the most primitive groupings of the atoms. The wonder is that we should be able to look so far, that the structure of the crystal should be so finished and so unvarying from first to last that our observation of a crystal big enough to handle should tell us no more and no less than the properties of the one little unit of pattern. If the diamond in a ring were increased to the size of the earth the individual carbon atoms would only be about as big as tennis balls. Yet so faithful is the information concerning the diamond structure which the X-rays give us that we can measure the distances from atom to atom with an error less than 1 part in 1,000. This new power, which is surely wonderful enough, we naturally apply to the further elucidation of the problem which I described at the beginning. We try to find out, by fresh means, the relations between the properties of substances and the nature of the atomic structures of which they consist.

It might be objected that a crystal is something special and that most bodies do not show the perfect crystalline form. The difficulty is apparent, not real. In the first place, far more substances are crystalline than would be supposed, and actually every substance would develop more naturally into a perfect and characteristic crystal than into any other form. The crystal is the natural condition. Bodies which seem to us to present no crystalline appearance at all are often aggregates of minute crystals jammed together miscellaneously or held like a mush in a semi-liquid matrix. Often again, as in the case of liquids, the various atoms and molecules have not had time nor peace enough to arrange themselves as they would. Even if many of the substances in whose behaviour we are most interested, such as iron and steel, are far in form from the perfect crystal, yet we may expect to arrive in the end at an understanding of their structure by the separate examination of the few definite forms of crystal of which, as we know well, the whole mixed mass is compounded.

We may now go on to consider individual cases. It is, perhaps, natural to a new form of enquiry to deal with particular instances of its application as they have been so far,

made, rather than to attempt broad generalisations. As we consider each case let us look at it from the point of view already emphasised. Let us try to see how the properties of the whole crystal depend strictly upon and are, indeed, an index to the properties of the atoms and atomic combinations of which they are made.

The diamond is, perhaps, the best to begin with. Its unique qualities dispose us to expect a structure which is equally distinguished, and so it turns out to be. The structure is figured in the accompanying

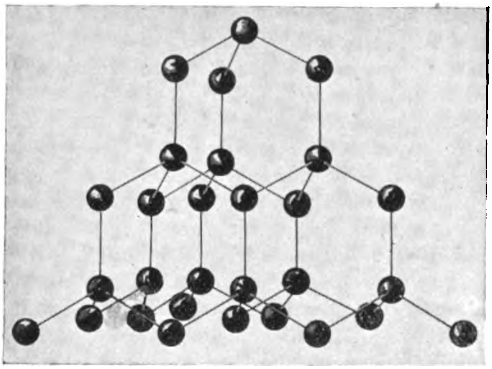


FIG. 1.

DIAMOND SHOWING HOW EACH CARBON ATOM LIES AT THE CENTRE OF GRAVITY OF FOUR OTHERS.

sketch. It may look at first sight somewhat complicated, but when it is examined closely it is found that the whole story is told in one sentence. Each atom has four neighbours regularly disposed about it. In other words, the four make a regular tetrahedron, and the first atom is at the centre of it. In the arrangement so determined by X-ray analysis we recognise at once an agreement with one of the most important deductions of the chemist, the so-called tetravalency of the carbon atom, which means a tendency to associate itself with its neighbours by four bonds of equal strength. The hardness and strength of the diamond are based on the simplicity and regularity of this tetrahedron arrangement, and, in addition, on the strength of the tie between atom and atom. We find that atoms are fastened together by bonds of two or three different types ; the one here illustrated is the strongest of all. Every atom, we know nowadays, consists of a central core, which is positively electrified, and of a sufficient number of negative bodies of a second kind called electrons to balance the positive charge on the core. The diamond is an example of many cases where neighbouring atoms share electrons and build them each into its own structure. It is somewhat analogous to the sharing of party-walls by the houses of a terrace. Yet it can be seen that the structure is obviously weaker in certain directions than in others. Such are the horizontal planes in the figure. These are called the cleavage planes. The diamond worker takes advantage of the fact, skilfully using cleavage instead of grinding. An excellent instance is to be found in the exhibit of the Crown Jewels in the Tower, where the manner of cleaving one of the great diamonds is shown. There is a second plane of cleavage, which is only used by workmen of the greatest skill as it is far harder to bring off the operation successfully. It is at right angles to the plane of the first kind. The tetrahedral form of structure is often reproduced in the form of the whole diamond, though no one, I believe, knows exactly why the faces of the tetrahedron are often rounded. This does not mean that the layers of the atoms are curved, but simply that they lie on one another like a series of steps.

A structure so tightly bound together is brilliantly clear from the optical point of view.

There is another form of carbon crystal, that of graphite or black lead, whose properties seem so different from those of the diamond, that it is hard to believe they are of the same element, and, moreover, of much the same construction. One common feature is of great interest, namely, the existence in both cases of layers of atoms arranged in hexagonal pattern. It is difficult to express in words, but the illustration (Fig. 2) will make it clear. Each atom is still bound to three of its neighbours by the same strong ties as before, but the fourth is broken in the case of graphite and a weaker, lengthier connection is substituted. All this is reproduced in the outward appearance of graphite. Its crystals are badly formed, but are more or less in hexagonal columns, which split up with the greatest ease into thin leaves at right angles to the column axis. So easy indeed is this cleavage that the pounding of a mass of graphite in a mortar is ludicrously ineffective. The leaves simply multiply themselves more and more. One leaf slides on another very easily, yet each leaf holds well together.

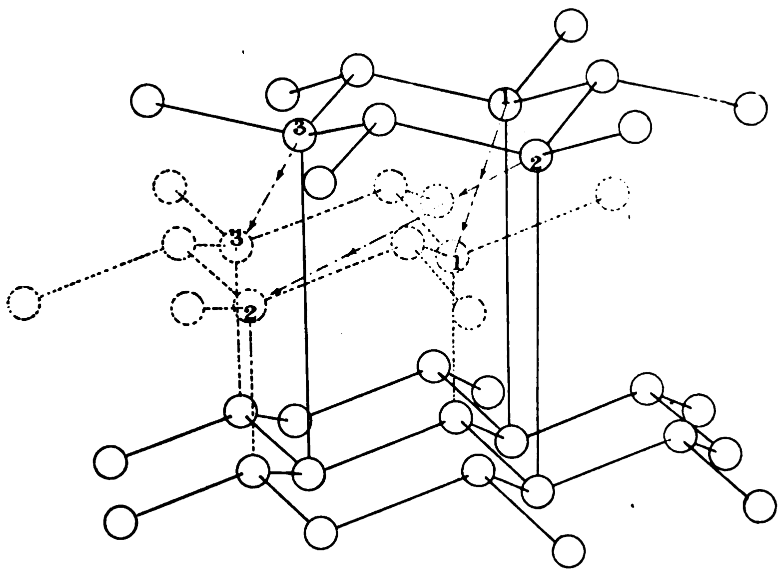


FIG. 2.—THE FINE LINES OF THE DIAGRAM SHOW THE STRUCTURE OF GRAPHITE. BY MOVING THE TOP LAYER TO THE POSITION SHOWN BY THE BROKEN LINES THE DIAMOND STRUCTURE IS OBTAINED.

It is the combination of these qualities that gives to graphite its lubricating powers. If you slip on the black-leaded hearthstone, it is because some of the layers which are sticking to the sole of your shoe slide on others which cling to the stone. I do not know that you can find a better instance of the relation between the external features of a crystal and its elementary structure. One change has converted the hard diamond into the soft slipping graphite, and it is easy to see that the results are exactly what one would expect from the nature of the change.

Now, we may pass on to another structure which is much like that of the diamond, namely, that of ice. The fundamental element of the design is again the fact that an atom, oxygen in this case, is surrounded symmetrically by four other atoms of like kind; the latter making a regular tetrahedron of which the former is the centre. But there is this difference between diamond and ice, that in the latter case, an atom of a second type, namely, hydrogen, is inserted between every pair of oxygen atoms. Thus, the immediate neighbours of each oxygen are four hydrogens. As every hydrogen has only two oxygen atoms as neighbours, there are twice as many hydrogens as oxygens in the structure. That is, of course, in agreement with the known composition of water.

Here, also, as in diamond, and graphite, are to be found layers in which the atoms are arranged in a hexagonal pattern. Arctic explorers have described a hexagonal structure in the ice floes; the block breaking up into hexagonal vertical columns resembling the pillars of the Giant's Causeway. But the most beautiful ice-crystals are found in the snowflakes or in the frost figures on the window. The forms are of an intricate delicacy based always on the hexagon and on the angle of 60°. The featheriness of the snow is the outward expression of the lightness of the pattern which resembles lace rather than a continuous structure. It is clear that the atoms could be packed more tightly; and that must have something to do with the fact that when ice is compressed it tends to melt. It is not easy to understand why the atoms join together in this of all possible ways. It is evident that particular points in the structure of one atom are linked up with corresponding points in the structure of another. Such considerations have, no doubt, to do with the internal structure of the atoms themselves.

It is a very curious fact that when a tetrahedral structure is found, as in the cases of diamond and ice, there are alterna-

tives with respect to one of the details of structure. Diamond following one of the alternatives is cubic; ice, following the other, is usually hexagonal. My friend, Dr. Whipple, has called my attention to a paper written about 100 years ago, in which the author describes ice crystals of peculiar form which he had found in the wooden bridge of Queen's College, Cambridge. It is possible to make out from the description that in this case the ice has grown as a diamond would do: the effect is described as one of great beauty and brilliance.

There is one feature of the diamond structure which is of great interest. The hexagonal ring of six carbon atoms is to be found in the structure as well as in the graphite flakes. Now a whole branch of chemistry of first rate importance is concerned with the examination of substances of which such a ring forms the essential element of design. When an atom of hydrogen is attached to each atom of carbon the ring with its fringe is the molecule of benzene. The ring is an extraordinarily persistent combination.

Organic chemists have learnt that they can detach at will one or more of the hydrogens, replacing them by certain other atoms, or by groups, such as the pair of oxygen and hydrogen atoms called the "hydroxyl group" or the "nitro group" of one nitrogen and two oxygens, and so on. In this way, an immense number of different substances are formed of widely varying properties. They occur in the work of the dye chemists, in the manufacture of explosives, in the study of living organisms and, in fact, constitute a class of bodies of first-rate importance. Chemists have inferred the existence of these rings by reasoning processes of really wonderful accuracy and power. It is natural to suppose that the ring which we find in our structures is the very ring which has been the concern of the organic chemist. We have tried to put this idea to the test, and so far I think with success. We can measure this ring in the diamond. It is just one hundred millionth of an inch across, and we can make good estimates of the enlargements that must result from such substitutions for the hydrogens as I have already described. We can then measure the space which the rings, modified or not, occupy in the organic crystal, and we get a very satisfactory fit. Here, for instance, is an illustration of the way in which the double rings that make naphthalene join themselves together. We have measured the size and form of the cell of the naphthalene crystal into which they pack. Two of them go into each cell. We have measured the length and width of the double ring assuming it to be the same as we find in the diamond, and we find that the agreement is good. Here again we may see in the structure of this little unit of pattern which contains two double rings everything that foreshadows the properties of the

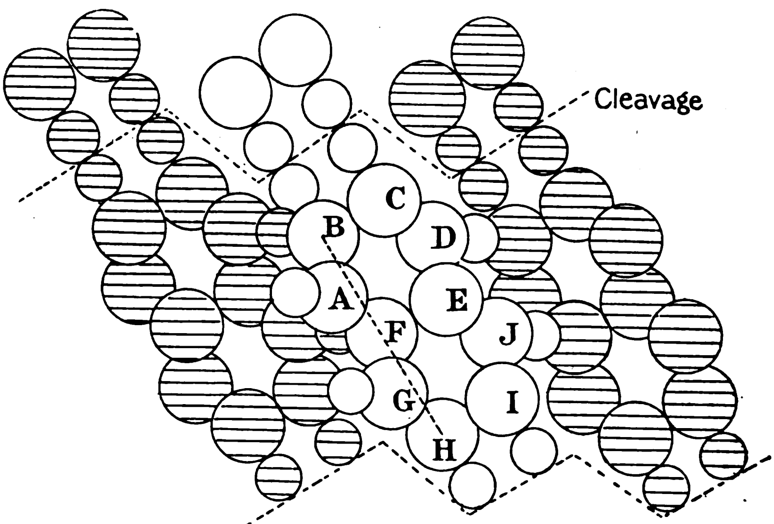


FIG. 3.—SHOWING MUTUAL RELATIONS OF THREE NAPHTHALENE MOLECULES AND PARTS OF OTHERS.

whole crystal. Why is the substance so light? Again because the structure is so lace-like and there are so many empty spaces. Why does it break up so easily into thin flakes? Because the molecules lie side by side somewhat like corn bent by the wind, and their side to side attachments differ from those that are end to end: the latter break more easily and the substance naturally splits up into layers, each of which is like a velvet pile. Why does the substance melt so easily? Because *all* the attachments of molecule to molecule are feeble and break up under disturbances due to heat. And so we may go on. If we attach a hydroxyl group to the side of the molecule we see the fibres of the pile open out sideways. If we attach it at the ends, we find the fibres grow longer; the two substances formed in this way are well known in the dye industry.

We have recently been examining the crystalline form of a number of the organic substances, and have learnt something of a very interesting system which governs the packing. It holds for all crystals apparently, but is very plain in the organic field. There are two stages in the process of the formation of the crystal from the original atoms.

First of all, the atoms are grouped into companies which the chemist calls "molecules." Chemistry has concerned itself largely with the study of the molecule, and particularly with the molecule in the free state, as in a liquid or a gas.

In the second stage of the process, the molecules are packed together to make the crystal pattern: it is this stage which is the subject of our present considerations, and which can be analysed by the X-ray methods.

Take a simple instance: two atoms of hydrogen and one of oxygen make up the water molecule. It is a company of atoms strongly tied together in an alliance which stands much rough treatment. The molecules can exist in a state of independence as steam or water vapour: in a condition of semi-independence they associate themselves together as water. We know well how much care has been given to the study of the water molecule in both these states. Now in the second stage the molecules are arranged side by side and end to end to form the crystal of ice. It has been necessary to take away much of their motion in order to induce them to take the new form. They are no longer running hither and thither, twisting and spinning with the energy of their motion. They lie more quietly now, still quivering, no doubt, but tied together so that they can no longer change appreciably their relative positions. They are now the crystal to be investigated by the new methods.

We find that when the molecules are packed into the crystal pattern—and they do not seem to suffer much in the process—they are put together just as anyone would try to pack a box with objects all alike in shape, but individually of irregular or, one might say, of awkward form. How would you pack a box full of boots? You would naturally put them in pairs, the right boot over the left in the familiar way. It is just such methods of packing that are followed in a crystal. It is convenient to illustrate by means of models. Here are a number of wooden "shoes" which are to represent molecules without symmetry in their form. Take four of them and put them together in the manner illustrated. The result is a pattern which possesses a

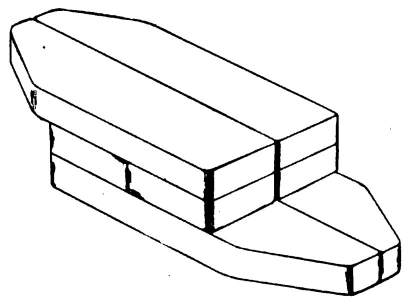


FIG. 4.

THE ARRANGEMENT OF THE FOUR "SHOES" SHOWS THE MUTUAL ORIENTATIONS OF THE FOUR MOLECULES IN A CRYSTALLIKE NAPHTHALENE.

certain amount of symmetry, the same, in fact, as that of the box in Figure 4. It is now a convenient form for packing. (Fig. 5.) It appears that a majority of known crystals pack together in this way. All of them show the symmetry that might be expected. They are exactly alike on either side of a dividing plane: in other words, they are exactly like their reflection in a mirror. They have, too, an "axis of symmetry"; a half turn about the axis brings no apparent change.

It is very interesting to observe the result of a different arrangement. Sometimes a set of four are arranged as in Figure 6, like two pairs of shoes back to back. There

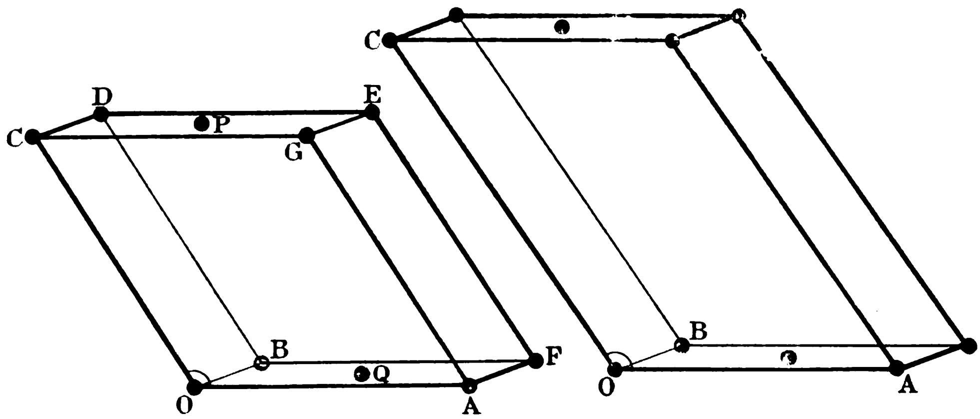


FIG. 5.—UNIT CELLS OF NAPHTHALENE AND ANTHRACENE DRAWN TO THE SAME SCALE.

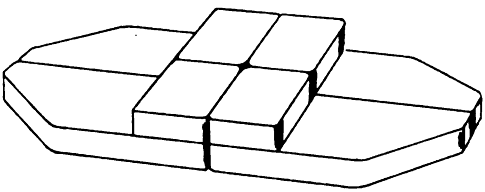


FIG. 6.

THE ARRANGEMENT OF THE FOUR "SHOES" SHOWS THE MUTUAL ORIENTATIONS OF THE FOUR MOLECULES IN A CRYSTAL OF RESORCINOL.

is a top and a bottom to this pattern, but a greater symmetry in other directions. We have recently examined a crystal called resorcinol, which is built on this pattern; its external form is shown in Fig. 7. The fundamental molecule is a benzene ring in which two hydrogens have been replaced by two hydroxyl (oxygen-hydrogen) groups. The crystal shows clearly different forms at its two ends, whose difference is shown in another very interesting way. If the crystal is warmed, one end of it becomes positively electrified and the other negatively. We have been able to go some way to the actual determination of

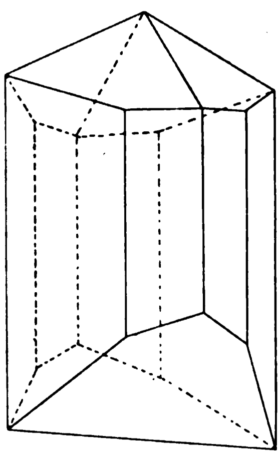


FIG. 7.

RESORCINOL. THE CRYSTAL IS SYMMETRICAL ABOUT EACH OF TWO PLANES WHICH MEET AT RIGHT ANGLES IN THE AXIS OF THE CRYSTAL. THE AXIS LIES VERTICALLY IN THE PLANE OF THE PAPER. BUT THERE IS NO SYMMETRY ABOUT A PLANE PERPENDICULAR TO THE AXIS.

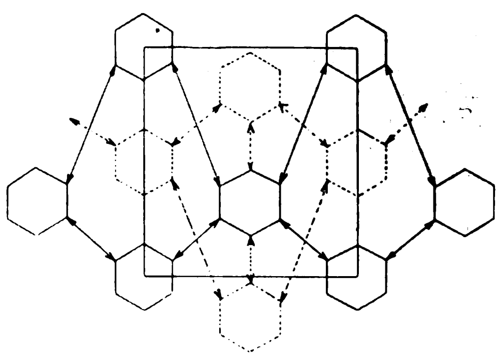


FIG. 8.

THE FULL LINES SHOW THE DISPOSITION OF THE RESORCINOL MOLECULES: WHICH ARE JOINED TOGETHER, PARTLY BY THE LONG HYDROXYL CHAINS, PARTLY BY SHORTER HYDROGEN CHAINS. THE BROKEN LINES SHOW THE NEXT LAYER, ABOVE OR BELOW THE FIRST.

the relative positions of the molecules: the results are shown in the figure. There are two sets of planes, which in the crystal occur alternately. In each, there are molecules arranged two different ways; one of which is a mirror image of the other. The arrangement is clearly governed by the necessity to fit the molecules together so as to accommodate the hydroxyl attachments.

Another case of great interest and importance is the two-molecule cell, the two being exactly alike. How would you pack a box with boots all right footed or all left footed? You cannot find a way of packing which will make the result symmetrical on either side of a plane. Neither do you find a crystal, built on such a basis, to have right and left symmetry. The crystal of tartaric acid, investigation of whose properties established the fame of Pasteur, is an excellent example. A recent publication by Mr. Astbury gives the proof that there are two molecules in the unit cell, and shows their relative arrangement. A model is shown in Fig. 9. The most striking physical

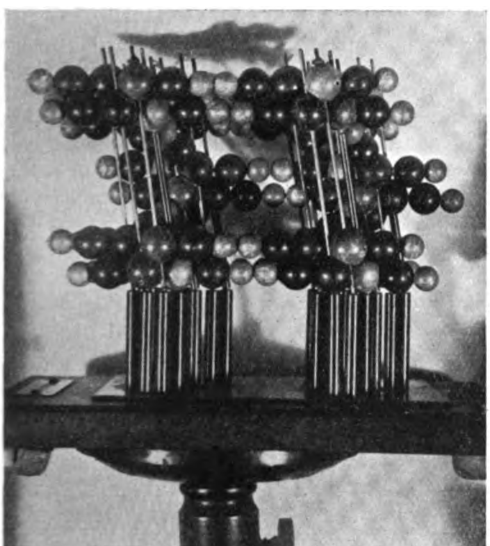


FIG. 9.—TARTARIC ACID.

THE SMALL BALLS ARE HYDROGEN ATOMS: THE LARGER BLACK BALLS ARE OXYGEN, AND THE LARGEST TWO GREY AND TWO BLACK ARE CARBON. THE SCALE OF THE MODEL IS TEN MILLION TO ONE.

property of the crystal is its power of rotating the plane of polarisation of light which traverses it. It has long been guessed that there must be some spiral arrangement in the structure: and this is beautifully confirmed in the model. There are, in fact, two spirals. This is somewhat unexpected, but it explains in a delightful way a property which has been obscure. One of the spirals is in the interior of the molecule itself and is certainly permanent when the crystal is dissolved. That accounts for the fact that tartaric acid in solution is "active," that is to say, can exercise its rotatory power. But the second spiral is a twist brought in by the necessity of fitting the molecules in their places. It is a peculiarity of the crystal structure, not of the molecule: it is a right handed screw if the first is a left-handed screw, and vice versa. Also it appears to be more powerful in its effect on the light; so that while the tartaric acid as a crystal rotates light in one sense, in solution it rotates light in the opposite sense. Here, again, the intricate effects of the whole crystal are directly referred to structural details.

It is to be observed that in this case there could be no question of the existence in the crystal of two molecules related to one another as right to left. For the mirror reflection of a right-handed screw is a left-handed screw, and the whole effect depends on a want of balance.

In this case also there is a pronounced plane of cleavage, passing through the points where the molecules join each other end to end.

Quartz is another instance of a crystal possessing rotatory power, and like tartaric acid it contains a special element in its construction. The X-ray methods make this thing very clear, and give us also some indications as to the structural system. The essential feature of the design is a spiral arrangement of the atoms of silicon and oxygen of which it is composed. The spiral character of the fundamental crystal is beautifully manifested in its outward form. Fig. 10 shows the two possible forms of the crystal, right-handed and left; a certain set of small faces gives to each crystal its spiral appearance.

These various examples have been given as illustrations of the tasks which the new method of crystal analysis undertakes. They belong to a new field of research, akin to chemistry in that they seek to refer the properties of substances to the nature of the elements of construction. Chemistry has, however, concerned itself in the main with the relatively free molecules of liquids and gases: here we deal with the properties of the solid. Our concern is to explain

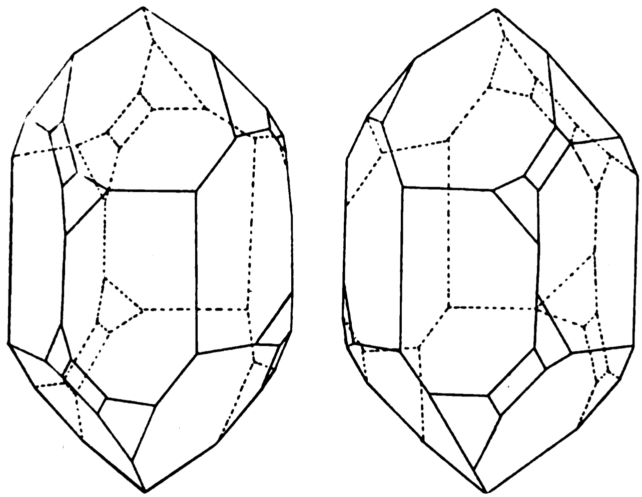


FIG. 10.
RIGHT AND LEFT HANDED QUARTZ.

the strength and elasticities of materials, the power of conducting electricity and heat, their electrical properties, optical properties; all these characteristics and many more in terms of the structure as revealed by the X-ray analysis. Here are, we may say, the contributions of the method to pure science.

It is natural to say something of the possible application to applied science. The properties of solid materials are of such fundamental interest to all arts and crafts that any new insight into their origin is necessarily important. But, at the same time, applications of science to industry are always unexpected in nature and time. What we have now to do from the purely scientific side lies plain before us: how and when any result will have practical value cannot be foreseen. The only fairly safe prophecy is that the first things we try to do with our new powers in order to help applied science will probably be all mistaken: and that final successes, which will surely come, are not even to be guessed at.

Much attention has been given to the immensely interesting problems of the crystallisation of iron and steel. Westgren in Sweden has done extraordinarily interesting work on the structure of the various forms of iron, α, β, γ and δ.

In this country, the effect of the crystalline form on the strength of a material has been examined in the case of the beautiful aluminium crystals of Professor Carpenter. The crystals are very easy to deform because certain planes of easy slip traverse the whole crystal, and these planes are always the first to give way. The X-rays show the structure of the crystals and the positions of the planes. When the large crystals are broken up into smaller, oriented in all ways, the material becomes stronger because in whatever way a stress is brought to bear some of the crystals are ready to bear it.

Kaolinite, which can be examined, though in the form of a very fine powder, shows clearly a crystalline structure: by the same methods it can be shown that the structure disappears when the temperature is raised to a certain point. The fact was anticipated by the scientific branches of the pottery industry: but this method provides a useful comfirmation.

Such instances are mere pointers in a direction in which we may hope there will be a great movement in time to come. Our first aim is to develop the new methods as pure science.

A broad straight road opens out before us and the going is good. As we travel along it we shall, doubtless, find many side turnings leading to useful applications, but we must not expect them until we are right opposite to them. Our first and obvious duty is to travel down the high road as far as it will take us.

DISCUSSION.

THE CHAIRMAN said that it was his privilege to propose a vote of thanks to the lecturer. Before he did so, he would like to

remind the audience that this was the sixth "Trueman Wood" Lecture. These Lectures were established with the object of bringing in regular sequence before the public some exposition of recent advances in subjects that interested the Society. The lecture which they had heard that evening was an excellent example of the sort of material which it was contemplated should be placed before audiences on these occasions. The exposition had not been devoted to methods of the investigation, but rather to the next object—the first product of the investigation. These investigations had been epoch-making. Sir William Bragg had devoted a perfect genius for experiment and the greatest ability in the interpretation of results to the examination of things which had previously been matter of speculation, and speculation which had gone only a very short distance. Sir William Bragg had verified or corrected, as might be, these speculations. He had provided absolute proof of what was previously only hypothesis. He had ascertained the proper methods of investigation, and applied them in various ways which would be of the utmost possible advantage in the investigation of everything which turned upon the minute structure and properties of the atom. He had carried the ascertainment of fact far beyond the previous reach of speculation. These were very great achievements. Sir William Bragg had attained this by applying his genius in a well directed manner, and he had, fortunately for this generation, not only the gift of experiment but also that of very complete, simple, and convincing exposition. In this and in other lecture rooms he had demonstrated his work, in one aspect or in another, combining his genius for investigation with his skill as an expounder. That evening they had had placed before them, under his own hand, a statement of the primary results in certain directions of the work he had done. He had used radiation of the lowest possible wavelengths to investigate the structure of crystals and the methods of behaviour of the atoms of which crystals were composed. The Society owed him a debt of gratitude for preparing a "Trueman Wood" Lecture on this subject. They regretted extremely—and he was quite sure Sir William Bragg regretted it quite as much as they did—that he was unable to be present that evening, but they were grateful to him for having, with so much care and so much consideration for the ignorance of some at least of the audience provided the material which they had found, not only palatable, but very readily digestible. This vote of thanks was really a double one, because thanks were due to Mr. Shearer for stepping into the breach and delivering Sir William Bragg's message. He had the greatest pleasure in proposing that a vote of thanks be accorded.

Mr. C. F. Cross, F.R.S., seconded the vote of thanks. He said that as Englishmen they might congratulate themselves that they had always had in this country a group of men who, working in the higher altitudes of science, were also ready to do their very best as expositors so as to bring the rest of them up to their level. Sir William Bragg was endeavouring to explore the structure of materials generally with a view to utilizing the results of his researches for the promotion of industry, and on that ground also the Society, which was interested in industrial matters, could feel grateful to him and to other workers in transcendental physics. Mr. Shearer had done his best as a substitute for his eminent master, and with conspicuous success.

The vote of thanks was carried unanimously.

Mr. Shearer briefly acknowledged the vote of thanks, and the meeting terminated.

GENERAL NOTES.

Mineral Resources of Guatemala.—Except on the coastal plains, minerals are found in practically every part of Guatemala, and are equal, if not superior, to the mineral resources of other Central American Republics. The country has been prospected only to a limited degree, but silver, lead, copper, and zinc are said to be found quite generally. There is an extensive chrome deposit of very high grade, and manganese, antimony, mica, and placer gold also exist. The mineral development of Guatemala in recent years, writes the United States Consul at Guatemala City, has been almost exclusively in foreign hands, principally American, but English and Germans are also interested to a limited extent.

Cotton in Australia.—It is estimated that this year 4,000,000 lbs. of seed cotton will be treated at the ginneries in Queensland, or four times the quantity dealt with last year. Further land is being reclaimed, and 1,000,000 more acres will shortly be available for cotton growers. Other States of the Commonwealth, according to *United Empire*, are seriously considering the prospects of cultivation, including Western Australia, New South Wales and the Murray River district.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

Monday, March 5 .. Engineers, Cleveland Institution of, Technical Institute, Middlesborough, 6.30 p.m.

Transport, Institute of, at the Institution of Electrical Engineers, Victoria Embankment, W.C., 5.30 p.m. Mr. G. S. Szlumper, "The Operation of a Railway-owned Port."

Royal Institution, Albemarle Street, W., 5 p.m. General Meeting.
University of London, University College, Gower Street, W.C., 5 p.m. Dr. A. D. Imms, "The Invertebrate Fauna of the Soil (other than Protozoa)."
Engineers, Society of, at Geological Society, Burlington House, Piccadilly, W., at 5.30 p.m. Mr. A. S. E. Ackermann, "The Physical Properties of Clay, and the Dynamics of Pile-driving."
Chemical Industry, Society of, at Engineers' Club, 39, Coventry Street, W., at 8 p.m. Dr. T. M. Legge, C.B.E., M.D., "Industrial Poisoning and the Works Chemist."

TUESDAY, MARCH 6 .. Civil Engineers, Institution of, Gt. George Street, S.W., 6 p.m.
Royal Institution, Albemarle Street, W., 3 p.m. Sir Arthur E. Shipley, "Life and its Rhythms." (Lecture II.)
Photographic Society, 35, Russell Square, W.C., 7 p.m. Mr. K. C. D. Hickman, "An Electric Indicator for Washing Troughs."
Oriental Studies, School of, London Institution, Finsbury Circus, E.C., 5 p.m. Professor Sir E. Denison Ross, "Early European Intercourse with the East."
United Service Institution, Whitehall, S.W., 3.30 p.m. Anniversary Meeting.
University of London, University College, Gower Street, W.C., 5.30 p.m. Mr. J. H. Helweg, "Contemporary Danish Literature." (Lecture V.) At King's College, Strand, W.C., 5.30 p.m. Prof. H. W. Carr, "Physical Causality and Modern Science." (Lecture III.) 5.30 p.m. Sir Bernard Pares, "Contemporary Russia from 1861." (Lecture VII.) Mr. A. J. Toynbee, "The Expansion of Europe Overland; the Route of the Steppes." (Lecture III.) At the London School of Economics, Houghton Street, W.C., 5 p.m. Mr. A. W. Flux, "Statistics, before, during and after the War." (Lecture III.)

WEDNESDAY, MARCH 7 .. Royal Society, Burlington House, Piccadilly, W., 4.30 p.m.
Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.
Archæological Society, Burlington House, Piccadilly, W., 5 p.m. Dr. C. Fox, "The Distribution of Population in the Cambridge Region in Early Times."
Central Asian Society, at the Royal Society, Burlington House, Piccadilly, W., 5 p.m. Sir John Jordan, "China and the Powers."
British Decorators, Institute of, Painters' Hall, Little Trinity Lane, E.C., 7.30 p.m. Mr. G. Murray, "Colour Decoration."
Optical Society, Imperial College of Science, South Kensington, 7.30 p.m. Mr. H. D. Taylor, "Optical Computation."
Historical Society, 22, Russell Square, W.C., 5 p.m. Mr. C. Johnson, "The System of Account of the Wardrobe in the Reign of Edward I."
Public Health, Royal Institute of, 37, Russell Square, W.C., 4 p.m. Major A. T. Frost, "Venereal Disease under Army Organisation."
Industrial League and Council, Caxton Hall, Westminster, S.W., 7.30 p.m. Mr. A. Dagleish, "Control of Industry."
Metals, Institute of, at the Institution of Mechanical Engineers, Storey's Gate, S.W., 10.30 a.m. Annual General Meeting.
Public Analysts, Society of, at the Chemical Society, Burlington House, Piccadilly, W., 8 p.m. (1) Mr. A. Lucas, "The Examination of Firearms and Projectiles." (2), Mr. R. C. Frederick, "The Interpretation of the Results obtained in the Analysis of Potable Waters." (3), Mr. Sydney B. Phillips, "Determination of the Purity of Vanillin."
University of London, University College, Gower Street, W.C., 5.30 p.m. Mr. I. C. Grøndahl, "The Work of Wergeland." (Lecture V.) 5 p.m. Sir John Russell, "The Chemical Activities of the Soil Population and their relations to the Growing Plant." 5 p.m., Sir Frederick Bridge, "Purcell's Operas." At King's College, Strand, W.C., 5.30 p.m. Sir Herbert Jackson, "Some Thoughts on the Relation of Science and Industry."
Sanitary Engineers, Institution of, at Caxton Hall, Westminster, S.W., 7.30 p.m. Mr. J. A. Coombs, "The Mechanics of the Activated Sludge Process."

THURSDAY, MARCH 8 .. Royal Institution, Albemarle Street, W., 3 p.m. Mr. T. Stevens, "Water Power of the Empire." (Lecture II.)
Metals, Institute of, at the Institution of Mechanical Engineers, Storey's Gate, S.W., 10.30. Annual General Meeting Continued.
Camera Club, 17, John Street, Adelphi, W.C., 8.15 p.m. Mr. H. Main, "A Pilgrimage to Provence."
British Architects, Royal Institute of, 9, Conduit Street, W., 5 p.m. Mr. W. Bayes, "Paintings and Architecture."
University of London, University College, Gower Street, W.C., 5.15 p.m. Mr. J. E. G. De Montmorency, "Distribution of Customary Law in England and France." At King's College, Strand, W.C., 5.30 p.m. Prince D. S. Mirsky, "Three Russian Poets, Puskin, Leskor, and Blok." (Lecture I.) At the London School of Economics, Houghton Street, W.C., 6 p.m. Sir William Vincent, "Political Developments in India, from 1920 to 1922." (Lecture II.) At the London Hospital Medical College, Mile End, E., 4.30 p.m. Mr. W. A. M. Smart, "The Mathematical Basis of Physiological Problems." (Lecture VIII.)

FRIDAY, MARCH 9 .. London Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5 p.m.
Royal Institution, Albemarle Street, W., 9 p.m.
Japan Society, 20, Hanover Square, W., 5 p.m. Mr. Y. Suma, "Religious Life in Japan."
Metals, Institute of (Local Section), University, Sheffield, 7.30 p.m. Capt. F. Orme, "Further Notes on Britannia Metals."
Photographic Society, 35, Russell Square, W.C., 8 p.m. Mr. W. Sanderson, "Over the Gemmi to the Valley of the Rhone."
Malacological Society, at the Linnean Society, Burlington House, Piccadilly, 8 p.m.
Physical Society, at the Imperial College of Science, South Kensington, S.W., 5 p.m.
Astronomical Society, Burlington House, Piccadilly, W., 5 p.m.
Dyers and Colourists, Society of (Scottish Section), Glasgow, 7 p.m. Mr. J. E. Weber, "Peroxide Bleaching." (Local Section), George Hotel, Huddersfield, 7.15 p.m. Paper by Mr. S. Robinson.
University of London, King's College, Strand, W.C., 5.30 p.m. Mr. C. E. Joad, "The Case for Pluralism." (Lecture II.) 5.30 p.m., Dr. R. W. Seton-Watson, "Serbia and the Jugo-Slav Movement." (Lecture VIII.)

SATURDAY, MARCH 10 .. Royal Institution, Albemarle Street, W., 3 p.m. Sir Ernest Rutherford "Atomic Projectiles and their Properties." (Lecture IV.)
London County Council, at the Horniman Museum, Forest Hill, S.E., 3.30 p.m. Mr. H. N. Milligan, "The Great Sea Serpent."

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FRIDAY, MARCH 9, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

NOTICES.

NEXT WEEK.

MONDAY, MARCH 12th, at 8 p.m. (Cantor Lecture). J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards, "Accurate Length Measurement." (Lecture II.)

WEDNESDAY, MARCH 14th, at 8 p.m. (Ordinary Meeting.) SIR WILLIAM WARRENDER MACKENZIE, K.B.E., K.C., President of the Industrial Court, "Industrial Arbitration." LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, will preside.

FRIDAY, MARCH 16th, at 4.30 p.m. (Joint Meeting of Dominions and Colonies and Indian Sections.) LIEUT.-COL. SIR LEONARD ROGERS, C.I.E., F.R.S., F.R.C.P., F.R.C.S., Physician and Lecturer, London School of Tropical Medicine, "Recent Advances Towards the Solution of the Leprosy Problem." EARL WINTERTON, M.P., Under Secretary of State for India, will preside.

Further particulars of the Society's Meetings will be found at the end of this number.

THIRTEENTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 28th, 1923; THE HON. SIR CHARLES A. PARSONS, K.C.B., LL.D., D.Sc., F.R.S., Vice-President of the Society, in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Huberich, Charles Henry, D.C.L., LL.D., The Hague, Netherlands.
Leonida, Ingonieur Dimitrie, Bucharest, Roumania.
Napier, William Joseph, Auckland, New Zealand.
Oakes, Edgar Stanley, Calcutta, India.
Thurston, Joseph Marshal, M.D., Richmond, Indiana, U.S.A.
Weiss, Carl W., New York, U.S.A.

The following candidates were duly elected Fellows of the Society:—

Ardeshir, Hormasji, Bombay, India.
Chatterjee, Girija Bhusan, Saduhati, India.
Hamid, Khan Bahadur Diwan Abdul, O.B.E., M.L.C., Kapurthala, India.
Johnson, Alfred Sidney, M.A., Ph.D., Chicago, U.S.A.
Ryan, Paul, Tankerton, Kent.
Walsh, Charles Peregrine, Crondall, Hants.

A paper on "Heat-Resisting Glasses" was read by PROFESSOR W. E. S. TURNER, D.Sc., Head of the Department of Technology, University of Sheffield.

The paper and discussion will be published in a subsequent number of the *Journal*.

CANTOR LECTURE.

On MONDAY EVENING, MARCH 5th, MR. J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy-Warden of the Standards, delivered the first lecture of his course on "Accurate Length Measurement."

The lectures will be published in the *Journal* during the summer recess.

DOMINIONS & COLONIES SECTION.

TUESDAY, MARCH, 6th, 1923; THE RIGHT HON. L. S. AMERY, M.P., in the Chair.

A paper on "The Dominion and Colonial Sections of the British Empire Exhibition, 1924," was read by MAJOR E. A. BELCHER, C.B.E., Assistant General Manager, British Empire Exhibition.

The paper and discussion will be published in a subsequent number of the *Journal*.

RE-OPENING OF THE LIBRARY.

The Library, which has been entirely renovated and re-furnished, is now open to Fellows daily from 10 a.m. to 6 p.m. (Saturdays 10 a.m. to 1 p.m.)

Fellows can obtain tea between 4 and 6 p.m. at moderate prices.

SETS OF THE JOURNAL.

The undermentioned short sets of bound volumes of the *Journal* have recently been returned to the Society, and they will be presented to any Library which will purchase the remaining volumes required to bring the set up to date.

1.—Vols. 9-45 (1861-1897): the remaining Vols. 46-70 can be obtained for £9.

2.—Vols. 25-42 (1877-1894); the remaining Vols. 43-70 can be obtained for £10.

BINDING COVERS FOR JOURNALS.

For the convenience of Fellows wishing to bind their annual volumes of the *Journal*, cloth covers can be supplied, post free, for 2*s*. each, on application to the Secretary.

THE ALBERT MEDAL.

The Council will proceed to consider the award of the Albert Medal of the Royal Society of Arts for 1922 early in May next, and they therefore invite Fellows of the Society to forward to the Secretary on or before Saturday, March 24th, the names of such men of high distinction as they may think worthy of this honour. The medal was struck to reward "distinguished merit in promoting Arts, Manufactures, and Commerce," and has been awarded as follows in previous years:—

1864, Sir Rowland Hill, K.C.B., F.R.S.

1865, His Imperial Majesty, Napoleon III.

1866, Michael Faraday, D.C.L., F.R.S.

1867, Sir W. Fothergill Cooke and Sir Charles Wheatstone, F.R.S.

1868, Sir Joseph Whitworth, LL.D., F.R.S.

1869, Baron Justus von Liebig.

1870, Vicomte Ferdinand de Lesseps, Hon. G.C.S.I.

1871, Sir Henry Cole, K.C.B.

1872, Sir Henry Bessemer, F.R.S.

1873, Michel Eugène Chevreul, For. Memb. R.S.

1874, Sir C. W. Siemens, D.C.L., F.R.S.

1875, Michel Chevalier.

1876, Sir George B. Airy, K.C.B., F.R.S.

1877, Jean Baptiste Dumas, For. Memb. R.S.

1878, Sir Wm. G. Armstrong (afterwards Lord Armstrong), C.B., D.C.L., F.R.S.

1879, Sir William Thomson (afterwards Lord Kelvin), O.M., LL.D., D.C.L., F.R.S.

1880, James Prescott Joule, LL.D., D.C.L., F.R.S.

1881, Professor August Wilhelm Hofmann, M.D., LL.D., F.R.S.

1882, Louis Pasteur.

1883, Sir Joseph Dalton Hooker, K.S.C.I., C.B., M.D., D.C.L., LL.D., F.R.S.

1884, Captain James Buchanan Eads.

1885, Sir Henry Doulton.

1886, Samuel Cunliffe Lister (afterwards Lord Masham).

1887, Her Majesty Queen Victoria.

1888, Professor Hermann Louis Helmholtz.

1889, John Percy, LL.D., F.R.S.

1890, Sir William Henry Perkin, F.R.S.

1891, Sir Frederick Abel, Bt., G.C.V.O., K.C.B., D.C.L., D.Sc., F.R.S.

1892, Thomas Alva Edison.

1893, Sir John Bennet Lawes, Bt., F.R.S., and Sir Henry Gilbert, Ph.D., F.R.S.

1894, Sir Joseph (afterwards Lord) Lister, F.R.S.

1895, Sir Isaac Lowthian Bell, Bt., F.R.S.

1896, Professor David Edward Hughes, F.R.S.

1897, George James Symons, F.R.S.

1898, Professor Robert Wilhelm Bunsen, M.D., For. Memb. R.S.

1899, Sir William Crookes, O.M., F.R.S.

1900, Henry Wilde, F.R.S.

1901, His Majesty King Edward VII.

1902, Professor Alexander Graham Bell.

1903, Sir Charles Augustus Hartley, K.C.M.G.

1904, Walter Crane.

1905, Lord Rayleigh, O.M., D.C.L., Sc.D., F.R.S.

1906, Sir Joseph Wilson Swan, M.A., D.Sc., F.R.S.

1907, The Earl of Cromer, O.M., G.C.B., G.C.M.G., K.C.S.I., C.I.E.

1908, Sir James Dewar, M.A., D.Sc., LL.D., F.R.S.

1909, Sir Andrew Noble, K.C.B., D.Sc., D.C.L., F.R.S.

1910, Madame Curie.

1911, The Hon. Sir Charles Algernon Parsons, K.C.B., LL.D., F.R.S.

1912, The Right Hon. Lord Strathcona and Mount Royal, G.C.M.G., G.C.V.O., LL.D., D.C.L., F.R.S.

1913, His Majesty King George V.

1914, Chevalier Guglielmo Marconi, G.C.V.O., LL.D., D.Sc.

1915, Sir Joseph John Thomson, O.M., D.Sc., LL.D., F.R.S.

1916, Professor Elias Metchnikoff.

1917, Orville Wright.

1918, Sir Richard Tetley Glazebrook, C.B., Sc.D., F.R.S.

1919, Sir Oliver Joseph Lodge, D.Sc., LL.D., F.R.S.

1920, Professor Albert Abraham Michelson, For. Memb. R.S.

1921, Professor John Ambrose Fleming, D.Sc., F.R.S.

1922, Sir Dugald Clerk, K.B.E., D.Sc., LL.D., F.R.S.

PROCEEDINGS OF THE SOCIETY.

NINTH ORDINARY MEETING.

WEDNESDAY, JANUARY 31st, 1923.

SIR HUMPHRY D. ROLLESTON, K.C.B., M.D., LL.D., President of the Royal College of Physicians, in the Chair.

THE CHAIRMAN, in introducing the readers of the paper, said that the subject, "The relation between chemical constitution and antiseptic action in the coal tar dyes," was most important both from an economic and a national aspect, and also from its scientific and medical interest. The aniline dyes, originally discovered by Sir William Perkin in 1856, had before the war passed almost entirely into the hands of chemical manufacturers in Germany. It was probable that this was due to the comparatively slight endowment of organic chemists in respect to this subject in this country, and the wise encouragement extended to such chemists in Germany. Our overwhelming handicap in this respect become obvious early in the war, but it might be hoped that, in spite of difficulties, this would be permanently remedied by organisations in this country.

From a chemical point of view the difference in action due to an alteration in the structure of a synthetic body was a fascinating problem, and had attracted much skilled labour, as indeed was well shown by the names "606" and "914" applied to preparations eventually found, after the number of trials indicated, to be suitable by Ehrlich in his epoch making research on the chemotherapy of syphilis. In the seventies the work of Pasteur and Koch established the specificity of disease—namely, that an infectious disease was due to one kind of germ and to that alone; later it became known that after each infectious disease specific antibodies peculiar to the disease and preventing its recurrence appeared in the patient's blood. The conception of the production of specific drugs which should, when introduced into the body of the patient, kill the parasite (parasito-tropic) and not hurt the organs (or be organo-tropic) of the individual, was due to Ehrlich. Before the war Sir Almroth Wright and others, working on the effect of "potochin" on pneumococcic infections, attacked the same problem and insisted that the bactericidal drug should be mono-tropic or have a selective affinity for one germ only; this was a different view from the obvious one, since adopted, that there was a certain amount of group action, namely, that allied organisms were affected in a similar way by drugs.

That evening the problem of the relation of chemical structure to antiseptic action—a slightly different aspect of this question—would be elucidated by a happy combination of the two workers; Mr. Fairbrother, a most able chemist with a brilliant record in the war, was now attached to the British Dye-Stuffs Corporation; Dr. Arnold Renshaw was a physician-bacteriologist who also did good service in the war, and as a bacteriologist was able to judge of the staining and antiseptic action exerted on micro-organisms by the dyes that his chemical colleague provided. It was by such team work that real advances in knowledge were most likely to be obtained. It would be interesting to hear from them whether there was any relation between the power of a given dye to stain a special bacterium or protozoon on the one hand and its power to inhibit their growth or kill them on the other hand. This had been thought to be the case, especially by J. W. Churchman in America before the war. During the war much use was made of aniline dyes as antiseptics, such as acriflavine, malachite green, brilliant green, and rosaniline, and the Society would now hear an account of the factors in chemical structure which underlay the antiseptic power of the coal tar dyes.

MANN LECTURE.

THE RELATION BETWEEN CHEMICAL CONSTITUTION AND ANTISEPTIC ACTION IN THE COAL TAR DYES.

BY THOMAS H. FAIRBROTHER, M.Sc., F.I.C., and ARNOLD RENSHAW, M.D., D.P.H.

PART I.

CHEMICAL ASPECTS.

In presenting an account of our work on antiseptic action as related to chemical constitution in the coal tar dyes, we have decided to divide it up into several sections.

(i.) The chemical aspect.
(2) General applications of the work.
(3) Application of the results to treatment of disease.
(4) Further outlook.

We have started with the chemical aspect because it is this section which acts as the basis upon which the whole work is built.

In the section on general application we shall deal with such applications as relate to agriculture, sewage, etc., as distinct from the treatment of disease.

In the third section animal experiments carried out with the best of the dyestuffs will be described.

There have been prepared synthetically a very large number of dyes according to well defined methods and these have shewn that the dyeing property is dependent in some way upon structure, and that dyestuffs can be grouped together into a few distinct classes of organic compounds. The view

which has been most generally held is Witt's theory that

(1) The character of a dyestuff is derived from a group contained in it, called a chromophore.

(2) The body containing the chromophore (or the chromogen) is not a dye but becomes one by the entrance of a salt forming group called the auxochrome.

There have been various classifications of dyes all of which are more or less arbitrary. For some practical purposes it has been found convenient to classify them according to their behaviour on dyeing the textile fibres. In this case we get groups such as acid dyes, basic dyes, mordant dyes, ice colours, developed colours, etc. Other classifications are dependent on the chemical configuration of the molecule, that is to say, according to the chromophore group occurring in them. Although such a classification is open to much discussion, we decided to adopt it as a convenient basis for studying the antiseptic action of dyes as a whole, in relation to the configuration of their molecules. The classification we ultimately adopted was :—

1. The Azo Class.
2. The Triphenylmethane Class (including Diphenylmethane Dyes).
3. The Phthaleins or pyronines.
4. The Azines, in which we included those derived from diphenylamine :—thiazines, oxazines and safranines. The rosinduline and euhrodines and the Isocyanines have been included in this group.
5. The Acridines.
6. The Sulphur Dyes.
7. The Oxyketone dyes.
8. Dyes of the Indigo Class.

As the last three classes are insoluble in water, and their dyeing action is dependent on the use of other substances, such as sodium sulphide or mordants, they were not suitable for this work, and we, therefore, restricted our attention to the first five classes.

For an account of the characteristics of the various groups of dyes the reader must be referred to the many text books on dyestuffs.

The following may be recommended for this purpose :—

A Text Book of Dye Chemistry, Georg von Georgievics and Eng. Grandmougin.
Synthetic Dyestuffs and Intermediates, J. C. Cain and J. F. Thorpe.
Farben Chemie, Fierz.
Farbstoff Tabellen, G. Schultz.
Lehrbuch der Farbenchemie, Bucherer.

EXPERIMENTAL.

1. *Preparation of the Dyes and their Derivatives.*

In all cases these were laboratory-prepared or purified products. The dyes of commerce usually contain salt or dextrin as a diluent and also many commercial dyes are mixtures of dyes—small quantities of certain dyes being added to shade up to a standard.

By the courtesy of the British Dyestuffs Corporation Ltd., we were able to trace the life history of the dyes we used and we made every effort to obtain a chemically pure substance. In certain cases, where, owing to difficulties of isolation, it was impossible to free the dyes entirely from salt, the amount of salt was determined by a careful analysis and this amount allowed for in making up the standard solutions.

The dyes thus purified were made up in 1 per cent. solution whenever possible. In certain cases the solubility of the dye was less than 1 in 100 and in these cases suitable strength solutions were made up.

2. *Preparation of Inoculation Tubes.*

The stock dye solution was then added in bulk to a known volume of broth to make solutions of 1/500, 1/1000, 1/2000 or 1/5000 of the dye in sterile broth prepared from animal tissues. This dilution of dye in broth was then added in quantities of 8 cc to sterile plugged tubes and these were finally sterilised at 30lb. pressure for 30 minutes. In a few cases where the dye decomposes on heating (*e.g.* auramine O and some of the oxazines) special precautions had to be taken and sterility tests made prior to inoculation.

These dye broth tubes were inoculated with a large loopful of a recent culture in broth of the organism and incubation carried out at 37°C for 2 days, after which sub-cultures were made into broth, or, in the case of the coli typhoid groups on to lactose or mannitol fuchsin peptone water, when a further incubation of 48 hours of the sub-cultures was again made.

3. *Bacteria Used.*

The following bacteria were used to test the action of the dyes :—

B. Phloei, B. Subtilis, B. Anthracis, B. Diphtheriae, Streptococcus, Staphylo-

coccus, B. coli, B. dysenteriae (Shiga, Flexner), B. typhosus, B. paratyphosus A, B. paratyphosus B, B. lactis, B. Enteriditis (Gaertner).

4. *Results Obtained.*

The results we have obtained are tabulated. An examination of these tables will shew that certain dyes kill off the gram negative organisms, leaving the gram positive as Chrysoidine 1 in 1000.

Turning to the 1/5000 tables it is noted that auramine shews a strong antiseptic action, as, even at this big dilution, most of the organisms were inhibited.

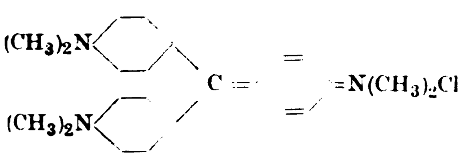
Reference to the results in the table will be made in the discussion of the results.

DISCUSSION OF RESULTS.

The Triphenylmethane Group.

Certain members of this group have shewn great activity as antiseptics, and there is promise of very successful future work in this group.

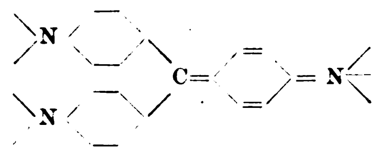
Crystal Violet in the form of the chloride :



at a dilution of 1/1000 killed off all the fourteen organisms under the conditions just described. At a dilution of 1/2000, however, it failed to inhibit anthrax and B para B.

This seemed to be a very convenient starting point from which to explore the possibility of the group either by further elaboration of the molecule or by simplification of it.

The first variation was to investigate the effect of various acid radicles, or to study the behaviour of salts other than the chloride. We prepared, therefore, a series of organic and inorganic salts from the base of crystal violet, including the tartrate, citrate, oxalate, and arsenite. These were put up against the organisms with crystal voilet chloride itself as a control, and within the limits of error very little difference was noted. The citrate was about the least effective. From the similarity in behaviour of the various salts of crystal violet base we concluded *that the antiseptic property was a function of the organic complex :*

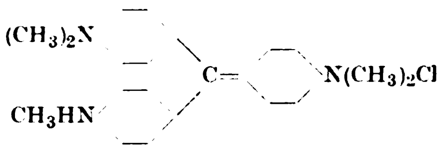


or of some portion of that complex, and that it is not influenced largely by varying the acid salt formation.

We next studied the behaviour of double salts of the crystal violet chloride with metallic chlorides. Two were prepared and purified, viz., the double salts of crystal violet chloride with the chlorides of zinc and lead respectively. On account of the unsuitability of the latter for animal work, we decided to study only the zinc chloride salt. This proved to be a more powerful antiseptic than crystal violet itself, and at a dilution of 1/2000 inhibited anthrax and B para B which crystal violet failed to do at that dilution. At the higher dilution of 1/5000 methyl violet zinc chloride killed 10 of the organisms, including anthrax, whereas crystal violet itself killed only seven definitely. The fact that the double salts of the dyes of this group with metallic chlorides are more powerful than the simple dye salts themselves, was confirmed again in the case of malachite green double salt of zinc chloride and dye chloride, and also in the case of auramine O $ZnCl_2$. In order to prove definitely that the effect was not due to the zinc chloride itself, the organisms were put up against solutions containing the same amount of zinc chloride alone in water and they all lived.

Thus the next conclusion with regard to the antiseptic action of the dyes of this group is, *that where a dyestuff exhibits antiseptic properties in its simple salt form, this antiseptic action is augmented by employing the dye in the form of a double salt with a metallic salt of the same acid as the dyestuff.*

We next studied the *effect of substitution in the amido groups.* A homologue was prepared containing six ethyl groups in place of the six methyl groups in crystal violet. This body behaved in a very similar manner to crystal violet chloride, and the effect of this substitution was found to be practically negligible. The same result was obtained in the case of methyl violet B, which contains only five methyl groups and one free hydrogen atom:—

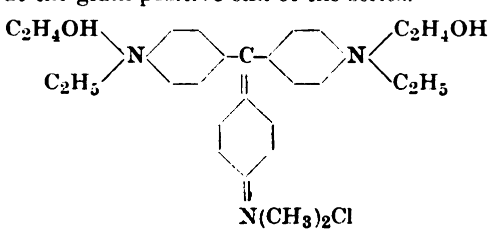


The effect of partial replacement of the methyl groups of crystal violet by ethyl groups was carefully examined, and in the formulae given below it is noticed how this has been varied.

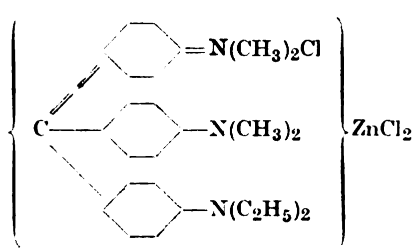
No. 2 contains 4 methyl groups and 2 ethyl groups
No. 3 contains 2 methyl groups and 4 ethyl groups $+ Zn\,Cl_2$
No. 4 contains 6 ethyl groups
Nos. 5 and 6 are 2 and 3 without $ZnCl_2$.

In all these cases a somewhat lower antiseptic action was noted than is the case with crystal violet itself, but of them all the one with four ethyl groups is the most powerful. Within the limits of experimental error one cannot find much effect from this substitution. It is quite evident, however, that simple alkyl substitution in this amido group is not a vital point, and methyl groups can be replaced by ethyl groups, partially or completely, with little effect.

In No. 1 two —OH groups have been added into the amido groups, and this had the effect of removing the antiseptic action at the gram negative end, but retaining it at the gram positive end of the series.



NO 1



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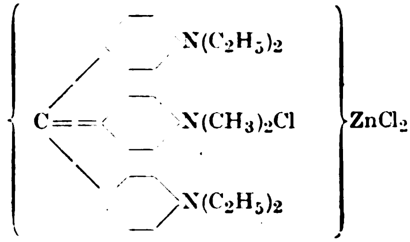

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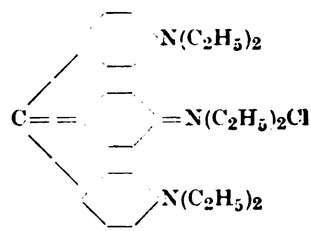

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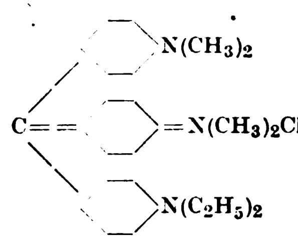

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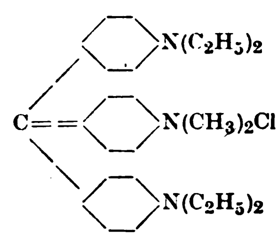
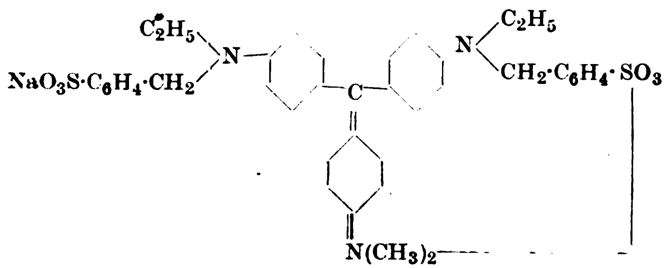


NO 6

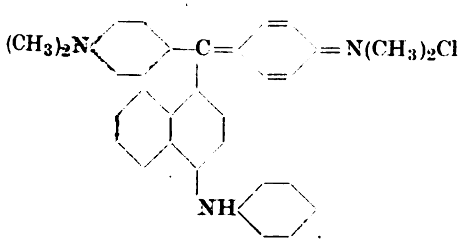
If, however, the methyl groups of two of the amido groups are replaced by higher alkyl homologues such as ethyl benzyl groups, the antiseptic properies are lowered. In these cases, sulphonation is necessary in order to make the dyestuff soluble. Thus formyl violet, which is prepared from dimethyianiline and ethylbenzylaniline sulphonic acid :



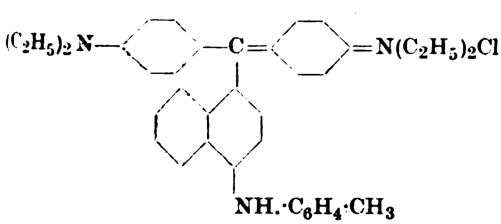
is far less potent than crystal violet or than the ethyl homologue. This leads to a further conclusion that *the presence of heavy side chains in the amino groups together with the presence of sulphonic acids is not favourable to antiseptic action in this group.*

Our next step in the examination of the group was to *study the effect of replacement of one of the aniline groups attached to the aliphatic carbon atom by other groups.*

One of the aniline groups was replaced by a substituted naphthylamine group (phenyl alpha naphthylamine) in Victoria Blue B.

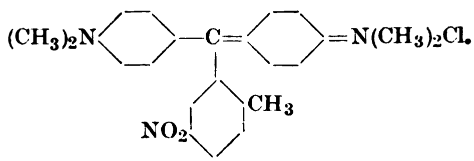


and in the ethyl homologue one of the aniline groups was replaced by tolyl alpha naphthylamine in Night Blue.



In these cases very much reduced antiseptic properties were noted in the case of bacteria. Night blue only killed five organisms at 1/1000 and none in any of the higher dilutions. Victoria blue B killed only four organisms at 1/1000. This dye, however, showed some activity against living protozoa.

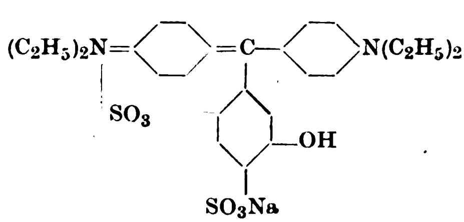
The aniline group was also replaced by p-nitrolouene in turquoise blue G,



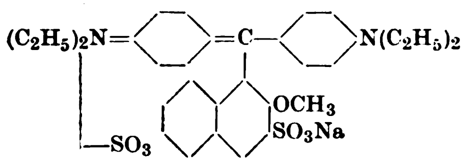
which shewed no antiseptic properties at all even at a dilution of 1/500 or against living protozoa.

A further variation was made by substituting the aniline group by sulphonic acids of the naphthalene series. Two greens were prepared from different naphthalene disulphonic acids. These shewed no antiseptic properties at all, and paramœcia were found alive in the solution after 24 hours. The same result was obtained with hydroxy sulphonic acids of naphthalene.

The dyestuffs Nos. 7, 8 and 9, shew the replacement of one of the aniline residues by other groupings. No. 7 is patent blue V made from diethylaniline and meta oxybensaldehydem disulphonated. This dyestuff shewed no antiseptic action. No. 9 shews a compound of diethylaniline and beta naphthol 3.6 disulphonic acid. This shewed no antiseptic action. No 8 shews the same body, but the hydroxy group has been methylated. The reason for this methylation was that dyestuffs of this series containing free hydroxy groups are rendered much faster to alkali and light by blocking the —OH group with an alkyl group. It was thought that this might influence the antiseptic properties, but no improvement was detected.



NO 7 (Patent Blue)



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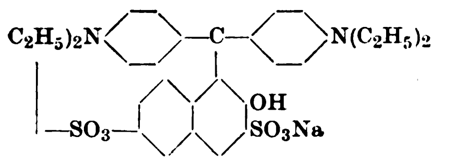


NO 9

These results indicate two conclusions :

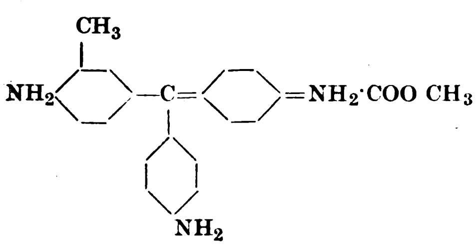
(*a*) *The introduction of acid groups into the complex in place of the aniline groups reduces the antiseptic action* as shown by the acid greens, turquoise blue, and patent blues.

(*b*) *That the antiseptic action is lowered even with basic substituents, if they are heavier and more complex as the substituted naphthylamines*, as shown by Victoria blue B, and night blue.

We were unable to work with the more simple naphthylamine derivative Victoria blue R on account of its low solubility.

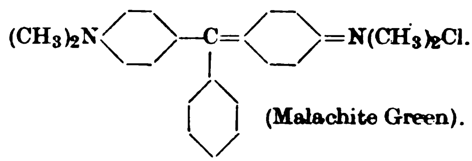
Having found that elaboration of the molecule of crystal violet by side chain variations and substitution of heavier groups on to the aliphatic carbon did not increase the antiseptic properties, but rather tended to reduce them, the next logical step was to study the effect of a simplified molecule.

Magenta is the first simplified form of crystal violet as it contains all the essential groups and three amino groups, none of which were substituted. This was employed in the form of the acetate.



It was found to be more powerful than crystal violet as it killed all the organisms at a dilution of 1/2000.

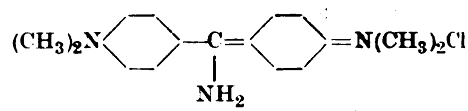
Simplifying the molecule still further by he removal of one of the amino groups entirely, the other two being substituted by alkyl groups, we obtain the dyestuffs Malachite green and brilliant green.



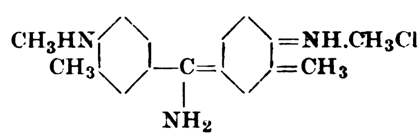
(Malachite Green).

This dye was more powerful than crystal violet, various salts, such as the oxalate, citrate and zinc chloride double salt were prepared, and exactly analogous results to those obtained with crystal violet derivatives were found. Brilliant green is the ethyl homologue.

A still more drastic simplification of the molecule involving the replacement of one of the aniline nuclei by $= NH$ or $— NH_2$ brought about a considerable increase in antiseptic properties and Auramine O.

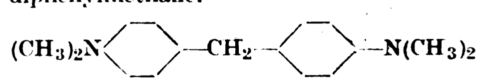


was extremely active both in the case of the inhibition of bacteria and the killing of protozoa. It killed twelve organisms (including anthrax) at a dilution of 1/5000 and killed paramœcia at a dilution of 1/20000 in 15 minutes. It was found that a re-arrangement of the molecule of Auramine O involving the change of two of the methyl groups from the amino groups into the nucleus as is obtained in Auramine G



caused a slight reduction in the antiseptic activity. This observation is confirmed in the safranine group.

An attempt was made to carry the simplification of the molecule still further by using the basic body tetramethyldiamidodiphenylmethane.



This body was prepared and purified by repeated crystallisation from alcohol and dissolved in exactly two equivalents of hydrochloric acid to give the dihydrochloride. This solution was put up against the

organisms. Unfortunately, a precipitation was brought about when the exactly neutral solution was employed, and to avoid this the broth had to be made more strongly acid so that although all the organisms were killed even at 1/2000 dilution, the result is not very trustworthy owing to the excessive acid present.

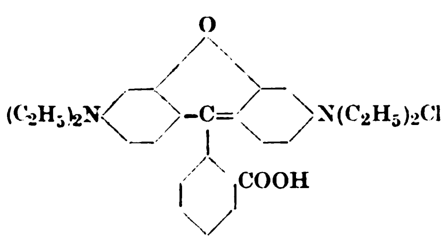
The results obtained in the Triphenylmethane Series may now be summarised.

The best results are obtained with the simpler types of the class. Change of one of the phenyl groups to a naphthalene grouping or a sulphonated phenyl grouping tends to reduce the antiseptic properties. For antiseptic action to be most marked it is essential to have two amino benzene nuclei linked up to an aliphatic carbon atom in para positions to the amino groups. The hydrogens of the amino groups may be replaced by alkyl groups like—C_2H_5 or $-CH_3$, but increase in the side chain does not increase the antiseptic action.

A further phenyl or aniline group may be introduced on to the aliphatic carbon (in the latter case in p. position to the amino group) without removing the antiseptic properties, or the aliphatic C may be attached directly to an amino or imino group, but if oxy sulphonic acids of the naphthalene series, naphthylamines, or substituted naphthylamines, or nitro alkyl substituted benzenes are introduced into the molecule the antiseptic action is considerably reduced.

The Phthaleins.

The consideration of this group follows naturally that of the triphenyl methane group for by examining the formula of Rhodamine B, the close resemblance to the triphenylmethane series is evident.

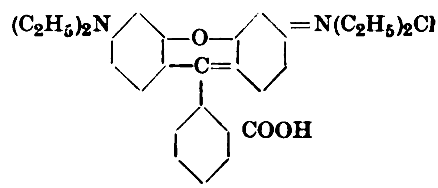


The group is, however, very different from the triphenylmethane group as represented by crystal violet or malachite green or auramine, and in antiseptic properties resembles more those members of the triphenylmethane group which have the third group replaced by the complex groups discussed—turquoise blue, night blue, etc.

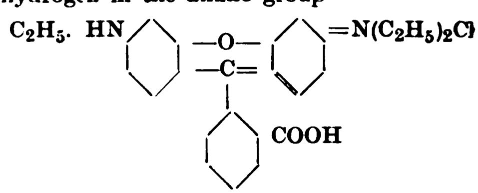
There are some antiseptic properties exhibited, but in no case as marked as crystal violet.

It seems probable that the reduction in antiseptic action in the group as a whole is due partly to the pyronine ring and partly to the nature of the third group attached to the central carbon atom, which group contains a carboxylic acid, and all our results indicate that acid groups of any description are unfavourable to antiseptic action.

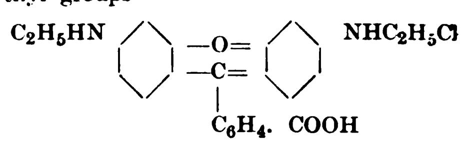
In the group itself there is an interesting internal variation, and the effect of substitution in the amino groups is very marked. Rhodamine B, in which all the hydrogens of the amino group are replaced by alkyl groups



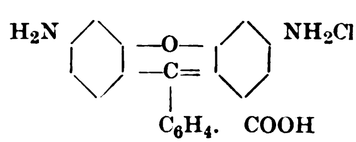
killed only one organism, B. Diphtheriae at a dilution of 1/1000. Rhodamine G. which contains 3 ethyl gronps and one free hydrogen in the amino group



killed four organisms, B anthrax, B diphtheriae, staphylococcus and streptococcus. Rhodamine 6G, which contains only two ethyl groups



killed eight organisms in a 1/1000 dilution. As a further development in this group we have obtained the unsubstituted body

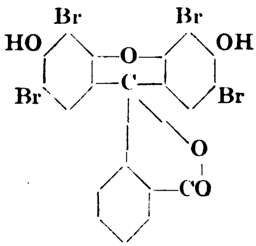


This substance is only slightly soluble even in presence of sufficient acid to give

the dihydrochloride and shews a strong fluorescence. We are at present examining the antiseptic properties of this body; from the behaviour of the other members of the series one would forecast that it would be the most powerful antiseptic of the group, but owing to the carboxylic acid group it would probably be less powerful than crystal violet.

In this group the chief conclusion so far is that increase in the Alkyl substituents of the amino groups tends to reduce the antiseptic action.

In the case of Eosin



the amino groups have been replaced by hydroxy groups, and thus instead of definitely basic properties acidic properties are associated with the molecule and antiseptic properties disappear altogether. Eosin in 1/1000 dilution failed to kill off any of the fourteen organisms.

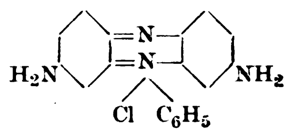
The general group conclusions are that in the strongly basic members of the group antiseptic properties occur to a marked degree. These properties are reduced by lowering the basic nature by alkyl substituents in the amino groups and disappear altogether where the amido groups are replaced by hydroxyl groups.

The Azine Group.

(*a*) *The Safranine Class.*—In this class so far, we have examined the simpler members, viz., phenosafranine, safranine T, tannin helio, methylene violet, and nigrosine, and a number of more complex derivatives.

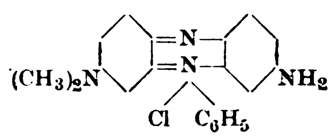
The results obtained indicate that the group is capable of very considerable antiseptic action, and it must be concluded that the azine group is very favourable to antiseptic action, though to get the maximum effect, basic substituents in the molecule are essential. It is possible to give to the safranines either an ortho or a para quinonoid structure, and probably there is a tautomeric balance between the two structures. For the purpose of this work we have adopted the general view of an orthoquinonoid structure which involves a quinquevalent nitrogen atom and thus the dyes are regarded as azonium compounds, Safranine T being meso phenyldiamidoditolylazonium chloride. As in the other groups studied, there is an internal variation of properties, the most active dye being phenosafranine and the least active induline or nigrosine.

Phenosafranine is the simplest in constitution and contains two unsubstituted amino groups.



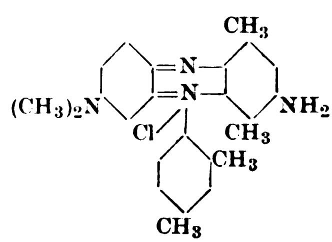
This dyestuff in a dilution of 1/1000 definitely killed twelve organisms and the other two, B anthracis and B para B were on the border line, sometimes being killed and sometimes not, under the conditions used.

Substitution of two methyl groups in one of the amino groups, as in methylene violet

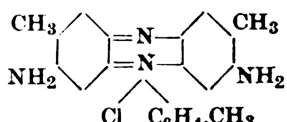


did not materially affect the antiseptic action and it killed 12 organisms. It was not so strong as phenosafranine, however, as it was definitely negative with B anthracis and B para B.

Further elaboration of the molecule by the introduction of more methyl groups into the aromatic nuclei (not further substituents in amino groups) in Tannin Helio



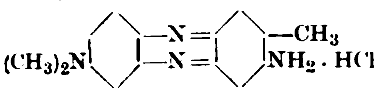
reduced the antiseptic action, an observation confirmed by the case of safranine T



where only nine organisms were definitely killed off. In the case of safranine T the interesting fact is noted that the introduction of methyl groups into the aromatic nuclei partially neutralised the effect of the two free amino groups. The only difference between phenosafranine and safranine T is the presence in the latter of three methyl groups substituted in the aromatic nuclei. The difference in antiseptic action is so great that one can only conclude that alkyl substitution in the aromatic nuclei tends to reduce antiseptic action. This offers a parallel to the case of Auramine O and Auramine G.

The lower antiseptic properties of nigrosine and induline, which have very complex molecules and have all the amino groups substituted by phenyl groups, confirm the previous observation that high elaboration of the molecule does not increase the antiseptic properties. The best antiseptic properties in the group are brought about by the simplest configuration embodying the azine ring with amino groups present in the nuclei.

Neutral red was not very active, but it killed five of the grampositive organisms at a dilution of 1/2000. It is more active than induline or nigrosine, but it is not as active as phenosafranine.



The investigation of the safranine series has been carried much further, the first extension being in the study of the acid safranines.

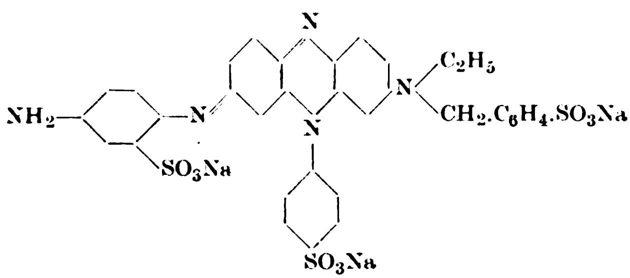
Acid cyanine B.F. is a typical example of an acid safranine. It contains three sulphonic acid groups in the various rings and also one free amido group. The antiseptic action manifested is nil under the conditions we have used.

No. 2 S shews that the alteration of the relative positions of the sulphonic acid groups does not alter the antiseptic action—again no organisms being killed.

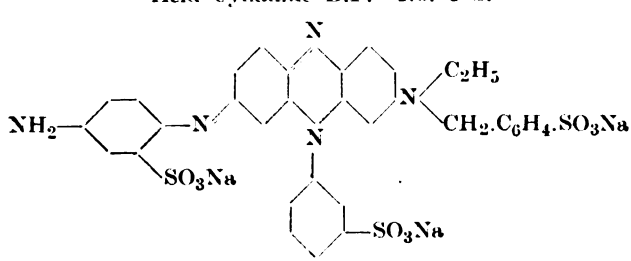
No. 3 S. In this case the heavy side chain in the substituted amido group of acid cyanine B.F. has been simplified and the dye is a derivative of dimethylaniline instead of ethylbenzylaniline. In this case although general antiseptic action is very poor the dyestuff shewed a specific action against B. Diphtheriae and at 1/2000 killed the organism. This result confirms our previous observation that the elaboration of the side chains reduces the antiseptic action and the simpler body. S 3 shews more antiseptic action than acid cyanine B.F.

In the case of No. S 4 the free amido group of acid cyanine B.F. is replaced by a nitro group and again no antiseptic action

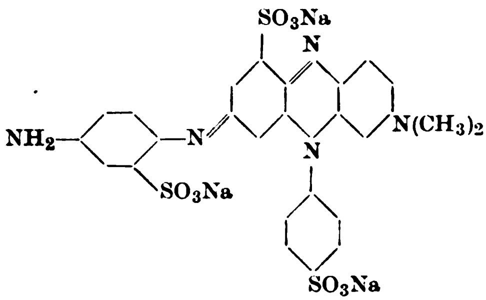
ACID SAFRANINES.



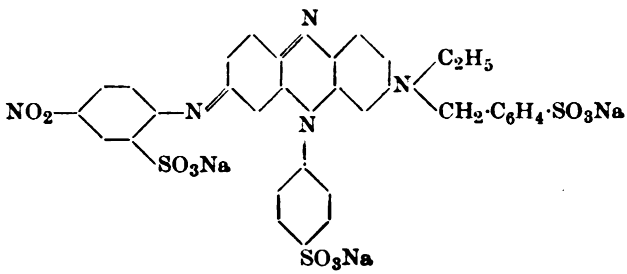
Acid Cyanine B.F. No. 1 S.



No. 2 S.



No. 3 S.



No. 4 S.

is noted. This is to be expected owing to the higher acidity due to NO_2 group. These four typical examples of the acid cyanines are sufficient to show that no antiseptic action is manifested by this series. The strong antiseptic tendencies of the simpler members of the safranine class (phenosafranine) have been completely removed, and thus it is obvious that the character of the azine group is completely altered by the introduction of acid groups and side chains into the molecule.

The Isorosindulines.

In these dyes we have the azine nucleus linked up with phenyl and naphthalene nuclei and containing free or substituted amido groups, but no acid groups in the molecule.

From the 1/500 table it is seen that antiseptic tendencies are being demonstrated again.

No. 5 killed all the organisms except B lactis at a dilution of 1/500.

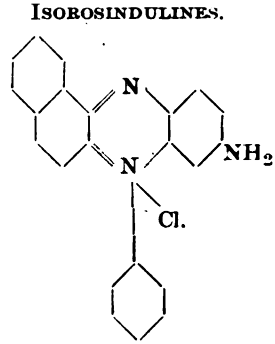
Amongst the rosindulines and isorosindulines it is noticed that elaboration of the molecule seems to enhance the antiseptic action.

No. 6 S is more antiseptic than No. 5 S, so that the introduction of a phenyl group into the amido group increases the antiseptic action.

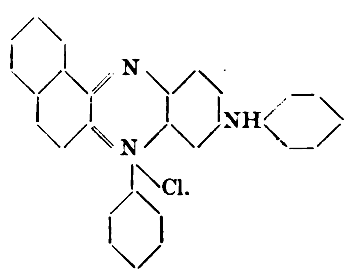
On the other hand, No. 7 S, which is the dimethyl substituted homologue of No. 5 S, shews lowered antiseptic action.

No. 8 S, which contains a further methyl group, shews lower antiseptic action than No. 5 S.

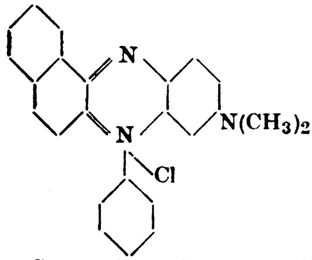
ISOROSINDULINES.



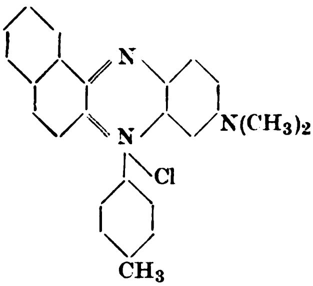
No. 5 S. isorosinduline



No. 6 S. phenylisorosinduline

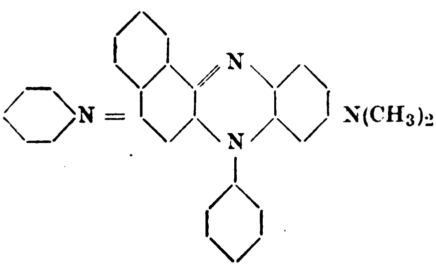


No. 7 S. Dimethylisorosinduline

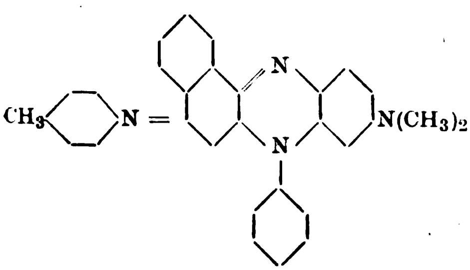


No. 8 S. Dimethyltollylrosinduline

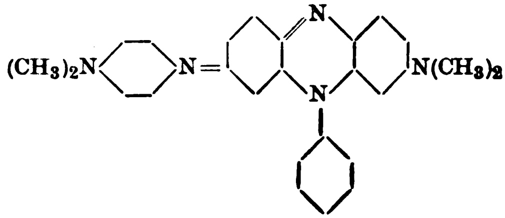
In the substances 9, 10 and 11, there is a slightly different constitution. The azine ring is brought into contact with an additional benzene nucleus through another nitrogen atom, and one might consider the grouping as a double azine grouping. In these cases the antiseptic action is considerably increased, and the bodies 10 and 11 show a very marked antiseptic action, all organisms being killed at a dilution of 1/2000.



No. 9 S.



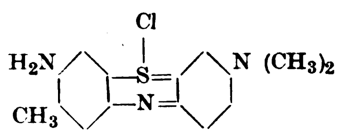
No. 10 S.



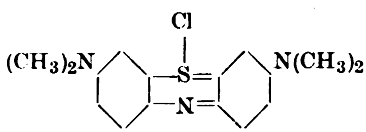
No. 11 S.

These more complex substances have been prepared in order to investigate the possibilities of such a grouping. The argument was that if the basic azine dyes exhibited antiseptic action, it was quite possible that further antiseptic properties could be brought about by incorporating an additional basic grouping attached through nitrogen. The connecting nitrogen atom is in para position to one of the azine nitrogens, and thus there is the arrangement of two nitrogen atoms, one ortho and the other para to a third nitrogen atom, all acting as connecting links between aromatic basic nuclei. Undoubtedly this arrangement has great possibilities.

(*b*) *The Thiazine Class.*—The examination of this class is interesting because it contains one of the earliest dyes to be used for pathological purposes—methylene blue. It contains the six membered ring, ring 4 C.S.N. In the group we have examined three members, toluidine blue, methylene blue, methlyene green, and work is in hand for preparing other members. Of these examined, toluidine blue

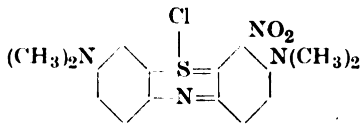


was the most active and killed ten organisms. Methylene blue



killed eight organisms, and it was found from the higher dilutions that methylene green was less powerful than methylene blue. This agrees with the previous observation that alkyl substitution in the amido groups lowers antiseptic action.

Methylene Green

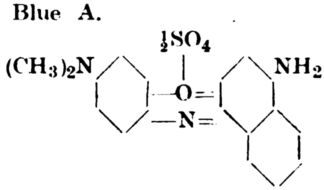


contains a nitro group and consequently is less basic than methylene blue and thus less antiseptic.

The introduction of the sulphur atom in place of one of the nitrogen atoms of the azine ring seems to lower the antiseptic properties, but still in many ways the thiazines are comparable with the safranines.

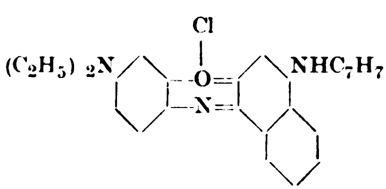
(c). *The Oxazines.*—The dyes of this group shew in a marked degree a definite selective action amongst bacteria. They all attacked the gram positive organisms, such as Timothy Grass, staphylococcus streptococcus, B diphtheriæ, B subtilis and B anthracis. Thus they showed their activity at the gram positive end of the series, and the gram negative or intestinal organisms were unaffected by the dyes, with one exception—Meldola's blue killed B disenteriæ shiga 1/1000.

Nile Blue A.

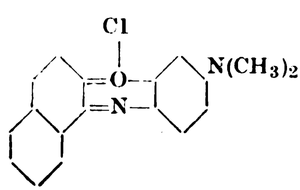


was the most powerful of the group (but this differentiation is made more from the results with protozoa than bacteria, in which latter case they all appeared identical).

Nile Blue 2B

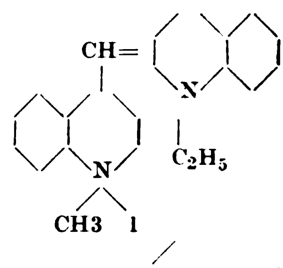


did not appear to be as powerful as the more simple body, Meldola's blue

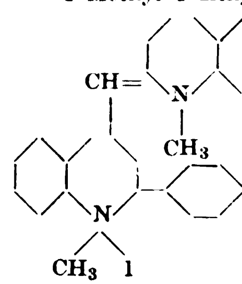


The differential action of these dyes is interesting, since they are fat stains and their influence as antiseptics may be due to their affinity for lipoids which may be present in the cells of the organisms. Their importance in regard to protozoa will be emphazised in the second part of the paper, and this powerful action on protozoa, coupled with the absence of effect on intestinal organisms, is of great importance in such problems as require the partial sterilisation of a mixture of protozoa and bacteria—say, for sewage purification.

We have carried out an investigation on the isocyanines or sensitol colours, and we will discuss them now, although their similarity to the acid cyanines ends with their name. Structurally they are quite distinct from the acid cyanines which, as we have seen, are azine compounds. The isocyanines are quinoline derivatives



1 Methyl 1 Ethyl 1 Isocyanine



1 Methyl 1 Methyl phenyl isocyanine.

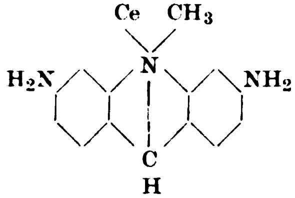
and are the methiodide compounds of the diquinoline bases. We have examined three of these bodies:

1 Methyl 1[1] ethyl isocyanine.
1 Ethyl 1[1] methyl isocyanine.
1 Methyl 1[1] methyl phenyl isocyanine.

These substances have not shewn any marked antiseptic action. At a dilution of 1/2000 they killed six of the organisms but failed to kill staph. aureus. We mention this finding, because other investigators have claimed remarkable results with the sensitol colours against staph. aureus. We have failed to detect any marked selective action or any great antiseptic action in these compounds.

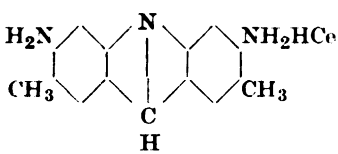
4. *The Acridine Class.*

We have examined acriflavine, acridine yellow R and acridine orange. Acriflavine

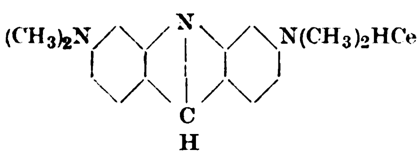


is the most powerful of the group, and also one of the most powerful of all the dyes we have examined. In its action on protozoa however, we have found it to be less potent than the oxazines or than certain of the triphenylmethane group.

The next one in order of antiseptic action is acridine yellow R



and the least powerful is acridine orange

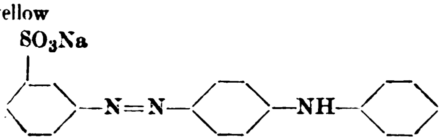


Thus these three members of this group conform to the general rules that increase in alkyl substitutes lowers the antiseptic properties, and that the best antiseptic action is shewn by the simplest members of any antiseptic class.

The Neutral Acriflavine made by British Dyestuffs Corporation is as powerful as acriflavine itself.

5. *The Azo Class.* Numerous representatives of this large group of dyes were used, and as a rule negative results were obtained.

Simple amido azo colours like metanil yellow



which contain one—N=N—group shewed no signs of antiseptic action even at a dilution of 1/500.

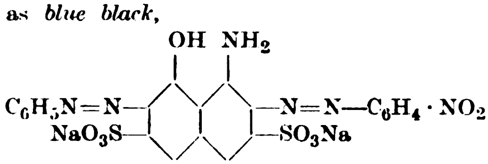
Chrysoidine

$$C_6H_5N{=}N \;.\; C_6H_3\ (NH_2)_2\ HCl.$$

shewed antiseptic action amongst the gram-negative organisms, but this action is rather weak when one bears in mind its strongly basic nature. Chrysoidine is one of the few azo dyes which do not form typical colloidal solutions, and it dialyses quickly through parchment. Thus it may be more able to penetrate the cell walls than the others.

The oxy azo compounds have also negative results.

The primary dis azo dyes which are formed by the successive action of two diazo salts obtained by the diazotisation of a monamine on an amine or a phenol such as *blue black*,

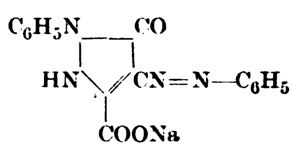


and the secondary dis azo dyes which are formed by the combination of diazotised amido azo dyestuffs with amines and phenols, such as Diaminogen Blue 2B again give negative results.

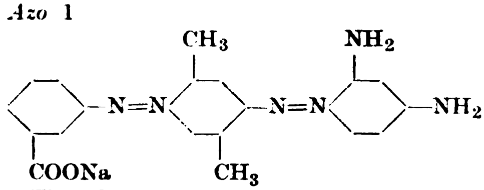
Similarly the dyes from tetrazo salts, such as Congo Red or Congo Corinth or Chrysophenine and the substituted ureas like Pink B.K. failed to shew any well-defined antiseptic properties.

It will be noted that most of the azo dyes so far used are those containing sulphonic acids. The reason for this is that by far the greater number of azo dyes contain sulphonic acid groups on account of making them soluble.

We have tried other azo dyes not containing sulphonic acid groups, but without success.



Azo 1

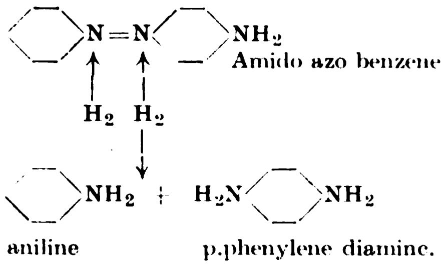


The first is an azo derivative of a pyrazalone containing a carboxyl group.

In the second dye we have two free amido groups and one carboxyl group and no sulphonic acid groups. The solubility of this second product is very low, and we did not obtain any satisfactory results from it.

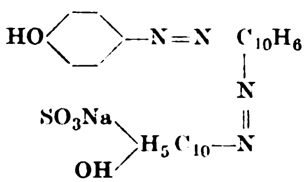
The results obtained in the azo group indicate that in concentrations of the dyestuff up to 1/500 the organisms are seldom affected. The azo dyes have fairly heavy molecules formed by linking big molecules together by the unstable group —N=N— and it seems quite likely that the organisms are enabled to break up the molecules at this double bond. In many cases decolorisation of the dye solution was noted after several hours contact with the organisms.

It is well known that azo compounds are broken up by nascent hydrogen at the —N=N—group, *e.g.*

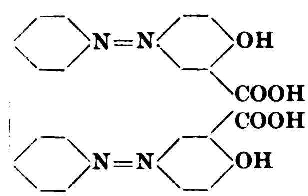


It is quite possible that the bacteria are in some way able to act in an analogous manner.

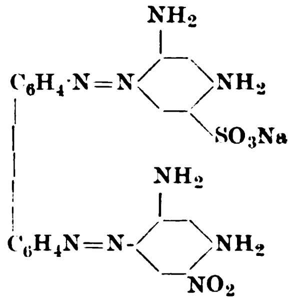
Two cases in which selective antiseptic action was noted in the azo class are worthy of notice. In the first era chrome black



shewed antiseptic action amongst the gram positive organisms but had no antiseptic action amongst the gram negative (intestinal) organisms. Owing to the general absence of antiseptic action in the azo class it seems obvious that we must look for the cause of this somewhere else than in the azo structure. It is probable that the organism has attacked the molecule at the —N=N—groups, and thus would liberate salicylic acid or p-amido salicylic acid, which would cause the antiseptic action manifested. Confirmation of this was sought by preparing chrysamine from tetrazotised benzidine and two mols. of salicylic acid and again selective action amongst the gram positive organisms was noted even at a dilution of 1/2000.



The azo dyes pyramine orange also shewed slight action in the gram positive organisms.



but again, considering that there are four free amido groups present, one would have expected greater antiseptic action.

General Conclusions.

Having dealt with the different groups in detail, and having shewn how antiseptic action varies with chemical constitution in each separate group it is possible to make a few general observations.

As a general rule dyes which shew any marked antiseptic action amongst bacteria and protozoa contain one or more amido groups in the molecule. The presence of amido groups is not enough to cause antiseptic action, but the absence of amido groups is enough to prevent any decided antiseptic action. The effect of amido groups in the molecule can be modified, and even completely neutralised, by the presence of certain other substituent groups in the molecule, such as sulphonic acid, carboxylic acid groups, nitro groups, substituted naphthalene, or naphthylamine groups, or by further alkyl or aryl substitution in the amido groups themselves, or alkyl substitution in the benzene nuclei.

In seeking for a possible explanation of antiseptic action, it is probable that other factors than mere chemical structure will have to be studied, because at the best the chemical formulæ we assign to the dyestuffs are but rough approximations to the truth.

Two observations are worthy of notice—in every case where decided antiseptic action is manifested, tautomeric change

in the molecule is possible, and also in every case of active antiseptic action the dyestuff is a molecular dispersoid, whilst those dyes forming colloid solutions shew very little tendency to antiseptic action.

Of late years a considerable amount of work has been done on the physical state of bodies, and many observers have examined the power of dyes to dialyse through a parchment membrane. Notable amongst these are the researches of Biltz, Höber, Teague and Buxton, Freundlich and Neumann and Vignon. A brief mention is only possible here, but these observers have divided dyestuffs into three classes :—

(1) Typical molecular dispersoids.
(2) Transition between molecular dispersoids and colloids.
(3) Typical colloids.

In the first class of molecular dispersoids fall picric acid, toluidine blue, chrysoidine, methylene blue, eosin, erythrosin, Bengal rose, acid magenta, auramine, safranin, methyl violet, patent blue.

In the transition state we find neutral red, the ponceaus, nile blue, acid violet.

Typical colloids are the congos, benzopurpurine, night blue, bismark brown and most of the azo colours.

We have held the view for a long time now that the physical state of a body has much to do with the antiseptic action. To be an efficient antiseptic a substance must satisfy two conditions :—

(1) It must kill the organism.
(2) It must have penetrative power to pass through the protective covering around the organisms.

Other conditions are also required before the antiseptic can be used on man, as will be seen in the later part of the paper, but these two are elementary conditions which must be fulfilled. If, therefore, a dyestuff has a colloidal nature in solution it is not likely to be an active antiseptic. Thus night blue, which has the triphenylmethane structure of a basic character and should, therefore, be antiseptic, shews no antiseptic properties. Teague and Buxton, Freundlich and Neumann and Biltz all state that it does not dialyse at all, and this probably accounts for its nonantiseptic nature. Thus it is seen that it is not sufficient for a body to have a certain structure which contains antiseptic groups alone—it must also have a physical condition which will enable those antiseptic groups to be brought into play.

It does not follow that because a dyestuff is a molecular dispersoid it will show antiseptic action, but it is quite definite that those dyes which have a colloidal nature are not good antiseptics. It is also possible that antiseptic action is dependent on the formation of a compound between dye base and the cell of molecules of the organism. It must be remembered that the dyes shewing antiseptic action are basic dyes, and there is a parallel to this in the action of basic dyes on animal fibres like silk. Knecht has shewn that when silk is placed in a solution of rosaniline hydrochloride the silk replaces the hydrochloric acid and the acid is set free and is found in the exhausted liquors and the silk and the rosaniline base form a compound together. If this view is correct, the compounds of dye and organism should conform to the chemical laws of constant composition, etc., and the establishment of this would be a difficult practical problem. It is possible that the principle of the Law of Mass Action could be applied, and that an equilibrium is set up—a balanced action which does not proceed to completion in either direction, but whose course is controlled by the active mass of either component of the system.

Thus, whilst antiseptic action does depend to a remarkable extent on chemical constitution, and whilst it is true that certain fundamental groups of atoms favour antiseptic action and others prevent it altogether, it is not possible to connect antiseptic action with intensity of colour, similar to Nietzski's rule—antiseptic action does not vary with the molecular weight, and there is no simple generalisation similar to Armstrong's quinonoid theory for explaining antiseptic action. The nearest parallel is Witt's chromophore generalisation, which could be applied by saying that certain groups favoured antiseptic action, and the action could be augmented by the addition of other groups, but this is very vague and does not help much.

The relationship between chemical constitution and non-antiseptic action, however, is more clear, and the discussions of the various groups have shown how antiseptic bodies have been rendered non-antiseptic by the replacement of certain groups by others. These findings will be of great use to us as we explore more intimately those fields which have shown promise so far.

(To be continued).

NOTES ON BOOKS.

COLOUR: CHARTED AND CATALOGUED. By E. Fellowes. London: Geographia, Ltd. £3 3s.

Many attempts have been made in the past to devise a scientific system of defining colours, such that it shall be possible to give a clear and accurate description of any individual tint—a system which will enable one to refer to colours as accurately as the musical notation enables one to refer to sounds. At present there is such an entire absence of any sort of system that the nomenclature of colours is in hopeless confusion. To convey an idea of any colour it is necessary to label it by a real or fancied resemblance to some well-known object. As a result, one finds endless confusion: to take paints, for example, scarcely two people will agree upon the exact colour indicated by such common terms as "stone colour" or "French grey."

The present work illustrates, in a series of thirty charts, with descriptive letterpress, the tints produced by combining primary colours in definite strengths and proportions. The standard of measurement adopted is the well known Tintometer of Lovibond. The charts are magnificently reproduced and the system devised might well form the basis of an accepted standard of colour values, by the use of which one could indicate any required tint accurately.

Unfortunately, the stumbling block has been the question of nomenclature. As with so many previous attempts, the essential difference between colours and coloured substances has not been recognised. If the author had devised a purely arbitrary series of names—or devised a numerical notation, the work would have been invaluable. But an attempt has been made to name each tint by reference to some natural object, with the result of increasing the confusion that already exists. Thus Cadmium orange surely means an orange coloured *substance* prepared from the metal cadmium, not a *colour* slightly yellower than normal orange. To the present writer, again, the tints labelled "cuttlefish," "winkle shell," and so on, do not appear at all convincing. It seems as hopeless to attempt to catalogue the infinite variations in the colour of natural objects in this way as it would be to combine the musical notation with the names of different musical instruments. It is a pity that a work prepared with the skill and patience required to attain such an accurately reproduced system of tints should perpetuate this fundamental error.

N. H.

COTTON IN THE SUDAN.

Some interesting particulars relating to cotton growing in the Sudan were given by Mr. W. H. Himbury, General Manager of the British Cotton Growing Association, in a paper read before the Textile Institute at Manchester.

The Sudan has a total area of 1,014,600 square miles. Its geographical area is larger than that of Egypt, and it is about half as large again in extent as the American Cotton Belt, or about the same size as Europe minus Russia. The Sudan is quite a new field for cotton growing, but it is capable of tremendous possibilities; in fact, its potentialities for the growing of long-stapled cotton are about the best we have. At present the production is about 40,000 bales of good Egyptian Sakel. It is in the Gezira District, a large plain situated between the two Niles immediately South of Khartoum, that the best cotton has been produced, and with the construction of proper irrigation works very big things are expected, for the importance of the Sudan to this country lies in the fact that, so far as we can see at present, no other part of the Empire can produce large additional quantities of cotton of the Egyptian type.

The British Cotton Growing Association has always taken a keen interest in the development of the Sudan, and was instrumental in helping to get His Majesty's Government to guarantee the interest on the first loan of three million sterling for the construction of the Dam on the Blue Nile, capable of supplying water to irrigate 300,000 acres of which 100,000 acres would be under cotton. A start was made with these works, but, unfortunately, it was found that the construction was costing a great deal more money than the estimates provided for, owing to the general rise in the cost of labour and raw materials due to the war, and at one time there was some risk of delay in carrying out the full scheme owing to the difficulties encountered by the authorities in making the necessary financial arrangements to meet the increased cost of construction. The Association, through its President, exerted every effort to avoid this calamity, and a tentative arrangement was agreed to by the Treasury enabling the work of the scheme to be continued for another season, pending further examination of the revised estimates of cost. The vast new scheme of irrigation has been finally approved and contracts have been placed for the work.

The scheme for cotton growing in the Sudan was initiated by the late Lord Kitchener, and it might be termed a socialistic scheme, for it ensures that the native who does the bulk of the work receives a fair reward for his labour. This, unfortunately, is not always the case in many parts of the world. The scheme is briefly as follows:—The cotton is grown on farms which have been established by the Sudan Plantations Syndicate at Tayiba, Barakat, and Hosh, of about 6,000 acres each, and a further farm of 10,000 acres is being opened at Wad el Naw. These four plantations, or units, will eventually form part of a whole scheme. The proceeds of the cotton crop are "pooled" and

the native who does the cultivation receives 40%; the Government, which supplies the land and the water, gets 35%; and the Syndicate, which undertakes the entire management, does the minor canalisation, ploughs the land and gives general direction of its cultivation, does the ginning, finances and markets the crop, etc., receives 25%. The population of the Sudan is comparatively small, but with a Government appreciated by the people and consequent settled conditions time will remedy this difficulty.

There are other propositions in the Sudan for rain-grown and irrigated cotton in the neighbourhood of Tokar, Kassala, etc. At Tokar, a large acreage is flooded annually, but, unless some scheme of irrigation is devised for the control and distribution of the waters of the River Baraka, cotton growing at Tokar is limited to about 25,000 bales. At Kassala, there is even a larger proposition so far as irrigation is concerned, to Tokar; but the great drawback to the immediate development of this large area is the absence of means of transport. At present, the cotton from Kassala is carried to Suakim, a distance of about 250 miles, by camel. A railway is, therefore, urgently wanted to connect Kassala with the existing Sudan railway at, say, Thamiam. Such a line would cost roughly about two millions sterling, and I do not know of anywhere where the money could be more usefully spent. It would mean the giving of much employment to our own engineering workers for the making of the rails, engines and rolling stock, and it would open up a valuable producing area. Further than that, I feel sure that shortly after this railway is completed at least 100,000 bales of first quality Egyptian cotton would be added to the supply, in addition to which there would be other valuable products, plus the transport of cattle, large numbers of which are raised and sent to Egypt.

I consider that the Sudan is certainly one of the most promising areas we have. Its capabilities are enormous, and there is little doubt that, eventually, it should produce fully one million bales of excellent cotton, although, of course, this quantity can only be obtained as the irrigation facilities are extended and when the necessary railway transport is provided to Kassala, Tokar, etc.

SZECHWAN WHITE WAX.

White wax, one of the most important exports of Szechwan, is chiefly found in the districts of Kiating, Chiewei and Ipin, and along the Yangtze River in the vicinity of these places. It is a substance deposited on trees by insects known as wax insects. Once a year—in March—they are collected from the regions on the border of Yunnan by the wax-worm raisers, and are placed on pollarded trees, either ash or privet, which are mostly grown in Kiating and neighbouring districts. Speed is essential in the removal of these insects, or they would hatch out before they get to the wax districts, and would thus be wasted. Therefore the coolies generally travel in relays so as to reach the destination in time for the hatching. When the moulting period is over, the worms begin to deposit the wax on the leaves of the trees. This process continues up to the end of August, when the wax is collected. After dissolving in boiling water, it is usually moulded into cakes of various sizes and shapes.

The total production of white wax in Szechwan according to a report of the Chinese Government Bureau of Economic information, amounts to 20,000 piculs annually. In the regions of production, the price per picul is usually quoted at about Tls. 150; but, as soon as the wax reaches Chungking, it is valued at about Tls. 180 per picul. Much of the produce is exported via Shanghai, Canton, Hankow and Foochow. Of late Canton has done the most business in this product.

CANTON SILK.

A report on the silk trade of Canton based on the fortnightly statements of Messrs. T. E. Griffith and Co., Ltd., shows that business was good throughout the whole year and witnessed some heavy buying coupled with extensive forward contracts exhausting local stock, so that the sixth crop of cocoons was sold out while still in the reeling stage. Transactions covered about 55,000 bales, 37,000 bales of which were for America and the remainder for Europe. Prices ranged from $830 early in the year, to $1,850 per bale towards the close, covering all styles. The latter figures, however, resulted in 20,000 bales of Japanese silk going to New York.

The heavy rains of June quarter did not do much harm, according to the *Canton Trade Returns*, but drought and an insufficiency of mulberry leaves during December quarter ruined the seventh crop. The silk year ends in April, and from reports to hand, Japanese firms hold a very fair share of the American demand, in spite of the fact that Canton quotations are highly sensitive to the Yokohama market. While the normal discount per bale locally is from $30 to $40 per picul, it rose as high as $100 during the March quarter. Short reels are mostly in favour everywhere, but a Lyons demand for long reels in the September quarter forced prices up to $1,520, due to the unreasonable demands of local spinners and an unexpected jump in French exchange. By the end of the year stock was practically exhausted, as, owing to the failure of the seventh crop through the drought, 75 per cent. of the filatures had ceased work. To local dealers this was no doubt more or less satisfactory, as with Yokohama in competition, had the seventh crop been good, and with a weakened American demand, prices must have considerably fallen.

GENERAL NOTES.

LAID-UP TONNAGE.—Addressing the Chamber of Shipping of the United Kingdom on February 22nd, the President, Sir Ernest W. Glover, Bt., said that at one period of the past year approximately 20 per cent. of the world's tonnage was laid up, though there was never anything like this percentage of British tonnage idle. Whilst at the beginning of the year we had 1,300,000 net tons, or 10 per cent., of British shipping laid up, this amount had been reduced by the end of the year to 700,000 tons, or, say, 5.4 per cent. of British tonnage. If they compared France they found that, by the November returns, 36 per cent. of the total fleet was laid up, whilst in America the latest return showed that over 60 per cent. of the Shipping Board tonnage was idle. There was reason, therefore, to believe that we in this country were making some progress towards the absorption into the world's markets of the surplus British tonnage. The laid up tonnage of America, now second only to this country in sea-carrying power, of course, loomed large on the shipping horizon and remained a factor to be considered in any estimate of the outlook we might be tempted to make as soon as freights advanced sufficiently to offer these idle ships work on a bare paying basis.

VICTORIA AND ALBERT MUSEUM.—Under the will of the late Miss M.B. Hudson, the Victoria and Albert Museum has become possessed of an important group of articles in old Sheffield Plate. The larger objects include three centrepieces for the dinner-table, one of them a singularly graceful design of pierced oval and circular dishes borne on curved branches, the whole reflected in the mirror of an octagonal plateau. It dates from about 1780, when the manufacture of Sheffield Plate had reached perfection of technique, and was guided in design by the fine taste developed on classic lines by such decorative artists as Flaxman and the brothers Adam. Similar elegance is shown in some of the tea-urns and other objects in the bequest, which includes also a few fine pieces of silver in the same refined style.

The Museum has also acquired out of the funds of the Murray Bequest four panels of stained glass from the recent sale of the Engel-Gros Collection in Paris. Three of these are Swiss and belong to the period of highest accomplishment; the fourth is South German. The panels are as follows:—(1) The Assumption of St. Mary Magdalene; Basle School, early 16th Century. The vivid effect producible by the process of scratching a design through a film of dark paint is here seen in its full force. The composition closely resembles the engraving of the same subject by Dürer. (2) The arms of the Town of Porrentruy, supported by angels; 16th Century—a panel showing extreme skill in the arrangement of colours. (3) The arms of the Counts of Kyburg, supported by a wild man and woman. Zurich school; end of the 15th century. This was formerly in the collection of the Baron de Trétaigne. (4) Adam and Eve. South German School; 15th century. The panels are temporarily exhibited in Room 139.

THE CLEANING OF MUSEUM EXHIBITS.—Investigations are being conducted at the British Museum as to the best methods of cleaning and restoring exhibits of various kinds. The work is under the supervision of Dr. Alexander Scott, F.R.S., who read a paper on the subject before the Society last year (*Journal of the Royal Society of Arts*, March 24th, 1922). The Department of Scientific and Industrial Research has just issued the second report on the investigations. It deals with prints and pictures, objects of stone, earthenware, silver, iron, lead, copper, bronze and wood. The problems still awaiting solution are very numerous and varied, and in view of the priceless nature of the objects dealt with, and the duty of preserving them as far as possible for the benefit of posterity, great interest attaches to Dr. Scott's work.

FOG DISPERSAL.—In the House of Commons on February 22nd, the Secretary for Air, Sir Samuel Hoare, was asked whether he was willing to carry out experiments over London or along the railways in fog dispersion, such as had been carried out with alleged success by the American Army Air Service with sand electrically charged from aeroplanes. He replied that full particulars of the experiments referred to had been called for by the Air Ministry but had not yet been received. Certain methods, had, however, been evolved for the dispersal of fog in a small confined space, but they did not appear to be as yet suitable for application on a large scale. The question was closely watched by his Department, and any method of fog-dispersal which promised to be effective would be carefully investigated and, unless the cost was prohibitive, given a practical trial.

MEETINGS OF THE SOCIETY.

ORDINARY MEETINGS.

Wednesday evenings, at 8 p.m.:—

MARCH 14.—SIR WILLIAM WARRENDER MACKENZIE, K.B.E., K.C., President of the Industrial Court, "Industrial Arbitration." LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, will preside.

MARCH 21.—F. W. EDRIDGE-GREEN, C.B.E., M.D., F.R.C.S., "Some Curious Phenomena of Vision and their Practical Importance." PROFESSOR E. H. STARLING, C.M.G., M.D., Sc.D., F.R.S., will preside.

INDIAN SECTION.

Friday afternoons.

APRIL 6, at 4 p.m.—GEOFFREY ROTHE CLARKE, C.S.I., O.B.E., I.C.S., Director-General Posts and Telegraphs, India, "Postal and Telegraph Work in India." LORD MONTAGU OF BEAULIEU, K.C.I.E., C.S.I., will preside.

June 1, at 4.30 p.m.—AUSTIN KENDALL, I.C.S., rtd., "The Indian Section of the British Empire Exhibition, 1924."

JUNE 15, at 4.30 p.m.—SIR JOHN H. MARSHALL, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture).

DOMINIONS AND COLONIES AND INDIAN SECTIONS. (Joint Meetings).

Fridays at 4.30 o'clock.

MARCH 16.—Lieut.-Col. SIR LEONARD ROGERS, C.I.E., F.R.S., F.R.C.P., F.R.C.S., Physician and Lecturer, London School of Tropical Medicine, "Recent Advances towards the Solution of the Leprosy Problem." EARL WINTERTON, M.P., Under Secretary of State for India, will preside.

APRIL 20.—SIR RICHARD A. S. REDMAYNE, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S., "The Base Metal Resources of the British Empire."

Dates to be hereafter announced:

WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Recent Developments in Surface Combustion."

MAURICE DRAKE, "The Fourteenth Century Revolution in Stained Glass Windows."

EDWARD PARNELL, "The Resources and Trade of Sarawak."

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards, "Accurate Length Measurement." Three Lectures. March 5, 12, 19.

SYLLABUS.

LECTURE II.—*March* 12. Comparison of line and end standards; control of temperature; derivation of multiple and sub-multiple standards; calibration of divided scales: surveying tapes and wires: comparisons of end-standards; Johansson gauges; "Millionth" measuring machines; tilting level comparator; optical methods; "wringing" films; some new methods.

LECTURE III.—*March* 19. Measurement of spheres and cylinders; Hertz compression; elasticity of "fit"; snap gauges; form gauges; horizontal projector; screw gauges; diameters; pitch; angle; thread form; vertical projector; internal measurements; plaster casts; measurement of gears.

E. KILBURN SCOTT, Assoc. M.Inst.C.E., M.I.E.E. "The Fixation of Nitrogen." Three Lectures. April 9, 16, 23.

HOWARD LECTURES.

Monday evenings at 8 o'clock.

STANLEY S. COOK, "Recent Improvement in Steam Turbines." Three Lectures. April 30, May 7, 14.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, MARCH 12 .. Surveyor's Institution, 12, Great George Street, S.W., 8 p.m.
Victoria Institute, Central Buildings, Westminster, S.W., 4.30 p.m. Rev. Prof. A. S. Geden, "Value and Purpose of the Study of Comparative Religion."
Geographical Society, 135, New Bond Street, W., 8.30 p.m. Mr. O. G. S. Crawford, "Air Survey and British Archæology."
University of London, King's College, Strand, W.C., 5.30 p.m. Rev. C. F. Rogers, "Ecclesiastical Music." (Lecture VI.) 5.30 p.m., Prof. R. Dyboski, "Poland." (Lecture VII.)

TUESDAY, MARCH 13 .. Petroleum Technologists, Institution of, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.30 p.m. Annual General Meeting, Presidential Address by Prof. J. S. S. Brame.
Sociological Society, 65, Belgrave Road S.W., 8.15 p.m. Mr. J. A. Hobson, "Bias in the Social Sciences."
Colonial Institute, Hotel Victoria, Northumberland Avenue, W.C., 8.30 p.m. Lord Ronaldshay, "Lands of the Thunderbolt: An Account of the Scenery and People of Sikhim, Chumbi and Bhutan."
Marine Engineers, Institution of, 85, The Minories, E., 6.30 p.m. Mr. W. A. Dexter, "The Development of the Air Pump for High Vacuum."
Anthropological Institute, 50, Great Russell Street, W.C.; 8.15 p.m. Miss M.

Edith Durham, "Bird-Men, and related Customs in the Balkans."

Metals, Institute of (Scottish Section), 38, Elmbank Crescent, Glasgow, 7.30 p.m. Annual General Meeting. Prof. J. H. Andrews, "Problems awaiting Solution." (North East Coast Section), Armstrong College, Newcastle-upon-Tyne, 7.30 p.m. Dr. W. H. Hatfield, "The Corrosion of Metals." (Birmingham Section), Chamber of Commerce, New Street, Birmingham, 7.30 p.m. Mr. G. L. Bailey, "Casting Temperature Conditions and the Properties of Phosphor-Bronze."

Architectural Club, Grosvenor House, Upper Grosvenor Street, W., 5 p.m. Mr. Nigel Playfair, "Architecture and the Theatre."

Royal Institution, Albemarle Street, W., 3 p.m. Prof. C. H. Seligman, "Rainmakers and Divine Kings of the Nile Valley." (Lecture I.)

Photographic Society, 35, Russell Square, W.C., 7 p.m. Annual General Meeting.

Transport, Institute of, at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C., 5.30 p.m. Mr. D. R. Lamb, "Some Present Day Transport Problems."

University of London, University College, Gower Street, W.C., 5.15 p.m. Prof. E. T. Whittaker, "Electric Fields in Atomic Physics." (Lecture I.) At King's College, Strand, W.C., 5.30 p.m. Prof. H. W. Carr, "Physical Causality and Modern Science." (Lecture IV.) 5.30 p.m., Sir Bernard Pares, "Contemporary Russia from 1861." (Lecture VIII.) 5.30 p.m., Mr. A. J. Toynbee, "The Expansion of Europe Overland; the Route of the Steppes." (Lecture IV.) At the London School of Economics, Houghton Street, W.C., 5 p.m., Sir Henry New, "Statistics before, during and after the War. (Lecture IV.) Food Supplies."

WEDNESDAY, MARCH 14 .. Literature, Royal Society of, 2, Bloomsbury Square, W.C., 5.15 p.m. Professor W. De la Mare, "Fiction in Verse."

Geological Society, Burlington House, W., 5.30 p.m.

United Service Institution, Whitehall, S.W., 3 p.m. Capt. S. M. Day, "Sea Training of the Merchant Service Executive Officer."

Public Health, Royal Institute of, 37, Russell Square, W.C., 4 p.m. Dr. J. H. Sequeira, "The Prevention of Congenital Syphilis."

Industrial League and Council, Caxton Hall, Westminster, S.W., 7.30 p.m. Mr. J. Murray, "Functions of Works Committees."

University of London, University College Gower Street, W.C., 3 p.m. Prof. E. G. Gardner, "Dante in his Works." (Lecture IV.) 5 p.m., Prof. P. Leon, "The Theory of Beauty." (Lecture V.) At King's College, Strand, W.C., 5.30 p.m. Sir Richard Gregory, "The Influence of Science." At the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C., 5.15 p.m. Prof. M. Walker, "The Control of the Speed and Power Factor of Induction Motors." (Lecture III.)

THURSDAY, MARCH 15 .. Aeronautical Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.30 p.m. Prof. B. M. Jones, "The Control of Aeroplanes at Slow Speeds."

Royal Society, Burlington House, Piccadilly, W., 4.30 p.m.

Antiquaries, Society of, Burlington House,, Piccadilly, W., 8.30 p.m.

Linnean Society, Burlington House, Piccadilly, W., 5 p.m.

Mining and Metallurgy, Institution of, at the Geological Society, Burlington House, Piccadilly, W., 5.30 p.m.

Royal Institution, Albemarle Street, W., 3 p.m. Col. E. F. Strange, "Japanese and Chinese Lacquer." (Lecture I.)

British Decorators, Institute of, Painters' Hall, Little Trinity Lane, E.C., 7.30 p.m. Mr. John Scott, "Decoration—Past Examples and Present Trend."

Child Study Society, 90, Buckingham Palace Road, S.W., 6 p.m. Sir Richard Gregory, "The Position and Character of Science in Schools."

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C., 6 p.m. Messrs. F. Hooper and J. W. Beauchamp, "Co-operation between the Architect and the Electrical Engineer" (Joint Meeting with the Royal Institute of British Architects).

Camera Club, 17, John Street, Adelphi, W.C., 8.15 p.m. Mr. C. P. Crowther, "The Man Behind the Camera."

British Architects, Royal Institute of, 9, Conduit Street, W., 5 p.m. Mr. H. S. Goodhart-Rendel, "Architecture — A Necessity or a Luxury."

University of London, University College, Gower Street, W.C., 5.30 p.m. Dr. A. Bugge, "The Viking Crusades and their Bearing on British Industry." (Lecture I.) 5.15 p.m., Mr J. E. G. De Montmorency, "French Customary Law." At King's College, Strand, W.C., 5.30 p.m. Prince D. S. Mirsky, "Three Russian Poets, Puskin, Leskor, and Blok." (Lecture II.) At the London School of Economics, Houghton Street, Aldwych, W.C., 6 p.m. Sir William Vincent, "Political Developments in India from 1920 to 1922."

Chemical Society, Burlington House, Piccadilly, W., 8 p.m. (1), Messrs. E. H. Usherwood and M. A. Whiteley, "The Oxime of Mesoxamide (Isonitrosomalonamide), and some Allied Compounds Part III.) Ring Formation in the tetra-substituted series. (2), Messrs. F. Challenger, A. L. Smith and F. J. Paton, "The Interaction of Hydrogen Sulphide Thiocyanogen, and Thiocyanic Acid with unsaturated compounds."

Transport, Institute of (North Western Section), Preston, 6 p.m. Mr. N. E. Box, "Heavy Road Transport."

FRIDAY, MARCH 16 .. Dyers and Colourists, Society of, College of Technology, Manchester, 7.15 p.m. Dr. Oxley, "The Regularity of Yars."

Royal Institution, Albemarle Street, W., 9 p.m. Dr. M. R. James, "Novels and Stories of J. Sheridan Le Fanu."

University of London, University College, Gower Street, W.C., 5.30 p.m. Sir Gregory Foster, "Lectures—their Use and Abuse." At King's College, Strand, W.C., 5.30 p.m. Dr. R. W. Seton-Watson, "Serbia and the Jugo-Slav Movement." (Lecture IX.) 5.30 p.m., Shakespeare Bibliographical Meeting.

Photographic Society, 35, Russell Square, W.C., 8 p.m. Mr. R. H. Lawton, "A Criticism of the Prints in the Affiliation Competition."

Mechanical Engineers, Institution of, Storey's Gate, S.W., 6 p.m. Second Report of the Steam Nozzles Research Committee.

SATURDAY, MARCH 17 .. Royal Institution, Albemarle Street, W., 3 p.m. Sir Ernest Rutherford, "Atomic Projectiles and their Properties." (Lecture V.)

London County Council, Horniman Museum, Forest Hill, S.E., 3.30 p.m. Miss A. Abram, "Travelling in the Middle Ages."

London Union of Commercial Institutes, Essex Hall, Essex Street, Strand, W.C., 6.30 p.m. Lord Askwith "The Value of French in the Commercial World of To-Day."

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FRIDAY, MARCH 16, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

NOTICES.

NEXT WEEK.

MONDAY, MARCH 19th, at 8 p.m. (Cantor Lecture). J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards, "Accurate Length Measurement." (Lecture III.)

WEDNESDAY, MARCH, 21st, at 8 p.m. (Ordinary Meeting.) F. W. EDRIDGE-GREEN, C.B.E., M.D., F.R.C.S., "Some Curious Phenomena of Vision and their Practical Importance." PROFESSOR E. H. STARLING, C.M.G., F.R.S., will preside.

FOURTEENTH ORDINARY MEETING

WEDNESDAY, MARCH 7th, 1923: THE RIGHT HON. LORD CLINTON, Forestry Commissioner, in the Chair.

The following candidates were proposed for election as Fellows of the Society :—

Davis, Professor Nelson Fithian, Sc.D., Lewisburg, Pennsylvania, U.S.A.
Gow, Jonathan Bertie, London.
Kapur, Sant Singh, Lahore, India.
Martin, Professor Dean W., Georgetown, Kentucky, U.S.A.
Nowak, Carl A., Sc.B., St. Louis, Missouri, U.S.A.
Parelwala, B. R., Bombay, India.
Thomas, Lieut.-Colonel Charles William, Stourbridge.
Tiddy, Richard Cyril, Calcutta, India.

The following candidates were duly elected Fellows of the Society :—

Ginsburg, Samuel Rowland, Mem. Am. Soc.C.E., Santo Domingo, W. Indies.
Lahary, R. S. D., Delhi, India.
Lednum, Edmund Townsend, Denver, Colorado, U.S.A.
Matthews, E., Bombay, India.

CANTOR LECTURE.

On MONDAY EVENING, MARCH 12th, MR. J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy-Warden of the Standards, delivered the second lecture of his course on "Accurate Length Measurement."

The lectures will be published in the *Journal* during the summer recess.

THE ALBERT MEDAL.

The Council will proceed to consider the award of the Albert Medal of the Royal Society of Arts for 1922 early in May next, and they therefore invite Fellows of the Society to forward to the Secretary on or before Saturday, March 24th, the names of such men of high distinction as they may think worthy of this honour. The medal was struck to reward "distinguished merit in promoting Arts, Manufactures, and Commerce."

The list of those who have received the medal since its institution in 1864 was printed in the last number of the *Journal.*

RE-OPENING OF THE LIBRARY.

The Library, which has been entirely renovated and re-furnished, is now open to Fellows daily from 10 a.m. to 6 p.m. (Saturdays 10 a.m. to 1 p.m.)

Fellows can obtain tea between 4 and 6 p.m. at moderate prices.

SETS OF THE JOURNAL.

The undermentioned short sets of bound volumes of the *Journal* have recently been returned to the Society, and they will be presented to any Library which will purchase the remaining volumes required to bring the set up to date.

1.—Vols. 9-45 (1861-1897): the remaining Vols. 46-70 can be obtained for £9.
2.—Vols. 25-42 (1877-1894); the remaining Vols. 43-70 can be obtained for £10.

PROCEEDINGS OF THE SOCIETY.

NINTH ORDINARY MEETING.

WEDNESDAY, JANUARY 31st, 1923.

SIR HUMPHRY D. ROLLESTON, K.C.B., M.D., LL.D., President of the Royal College of Physicians, in the Chair.

MANN LECTURE.

THE RELATION BETWEEN CHEMICAL CONSTITUTION AND ANTISEPTIC ACTION IN THE COAL TAR DYES.

BY THOMAS H. FAIRBROTHER, M.Sc., F.I.C., and ARNOLD RENSHAW, M.D., D.P.H.

(*Continued from page 295.*)

PART II.

PROTOZOA.

Applications :—Sewage.
Agriculture.
Medicine.

Since the time of Pasteur human endeavour has recognised the great role played by bacteria, and later by protozoa in the diseases of man, animals and plants, and the prejudicial effect which these agents could play in agricultural and industrial processes.

The application of much of this knowledge enabled Lister to achieve great results in surgery, but the methods used were essentially those in which a comprehensive attack was made on everything within their reach. All infective agents had to be killed if possible before gaining access to wounds. During the last quarter of a century great advances have been made in regard to the sterilisation of infective material *en masse*, and by a knowledge of the life cycle of various parasites, much disease has been prevented as a result of wise public health methods.

It must be admitted, however, that in the case of man and of animals, pathologists and bacteriologists have concentrated on the identification of the nature and cause of a disease rather than on the destruction of the infective agent.

For some years the method of immunisation held the field, probably largely due to the influence of Jenner and the subsequent attempts to extend his methods, and later by the introduction of diphtheria antitoxin, serums, and vaccines.

One cannot fail to concede that along these lines in conjunction with adequate chemical methods there are great hopes for further advances. In 1910 the remarkable investigations of Ehrlich opened a new era in the chemio-therapeutic treatment of diseases. After elaborate researches Ehrlich produced synthetically an organic substance which he asserted possessed powerful lethal action against the spirochaeta pallida of syphilis.

It was a drug which behaved like a sniper's bullet picking off and killing the infective agent only, without harming, to an appreciable extent, the tissue in which the spirochaetae resided.

In the course of his investigations he turned his attention to the wonderfully fertile field of organic substances—the synthetic dyes—as, for instance Trypan Red in Trypanosomiasis, and in one or two isolated cases he obtained promising results.

With these facts in our minds we decided to investigate the *whole* range of the aniline dyestuffs in their action against certain common bacteria and against certain protozoa.

We were unable to work with every organism for obvious reasons, their number being legion, but we made a careful selection so as to study representative groups of organisms. We wanted to know, first, whether selective action was possible; secondly, its chemical nature; and finally whether these results could be applied to the production of substances for use in medicine.

With regard to our study of protozoa we selected the Paramoecium (isolated from sewage) as a convenient example. Most of our work has been done on this organism although in certain cases we have studied other ciliates, such as Carchaesium and Vorticella; one of the flagellates euglena; filaria; and a strain of Trypanosome, T. venezuelense—obtained by courtesy of the Liverpool School of Tropical Medicine—from a South American strain.

In view of the large field of work to be covered, we have endeavoured to reduce our experiments to simple terms, and we have first tested our dyes with cultures of Paramoecia in accordance with the following method, eliminating the useless dyes and concentrating our further work on the more powerful.

All dyes were put up in a 1/100 solution in fresh tap water. A certain volume of the paramoecia culture was drawn up to a mark on a capillary pipette and an equal

volume of 1/100 dye solution drawn up, an air bubble separating the two liquids. The two liquids were then discharged as a drop on to a cover slip and the time of mixing noted.

This gave a 1/200 solution. An immediate examination was made and a further examination after 15 minutes.

If, after 15 minutes contact with the 1/200 dye solution, any paramœcia were still alive, the dye was rejected. If after 15 minutes contact with 1/200 dye solution no living paramœcia were detected, that dye was referred for further examination at a greater dilution. The next dilution employed was 1/1,000 solution of dye mixed with an equal volume of paramœcia as before giving a 1/2,000 dilution. This was subjected to the same time exposure as before, and if after 15 minutes living forms were present in solution, that particular dye was rejected ; if no living forms were detected after 15 minutes the dye was put up in the next dilution of 1/20,000.

Results.

The observations made are recorded in the tables.

An analysis of the results shows that the dyes which exerted the greatest action on the paramœcia were :—Nile blue A, Nile blue 2B, Meldola's blue, auramine O, ethyl violet, malachite green oxalate, magenta acetate, new series violets (1 & 2, especially).

In these cases the forms were affected at once at a dilution of 1/20,000, and some dead forms noted. With new series violet No. 1 and No. 2, immediate death was caused by a dilution of 1/20,000 and with a dilution of 1/40,000 death occurred within 15 minutes.

In the case of Meldola blue D, a new preparation of Meldola blue and zinc chloride, immediate death occurred in a dilution of 1/80,000, and within 2½ hours in a dilution of 1/160,000—a result which is surely noteworthy.

These figures should be compared with Neo Salvarsan solutions which, in a dilution 1/200 fail to kill paramœcia within two hours.

Of these dyes auramine O, ethyl violet, malachite green oxalate and magenta acetate were all very active in the case of bacteria, but the oxazines were only active amongst the gram positive organisms.

In this work on paramœcia we have practically eliminated the whole series of dye classes except the triphenylmethane group, which are highly bactericidal, and the oxazine group in which bactericidal action on the gram negative (intestinal) organisms is very poor, whereas paramœcia are killed off by it in a dilution of 1/20,000 in 15 minutes and at a much higher dilution after longer contact.

Selective Action.

We are now in a position to ask "Is there any selective action possible in regard to the action of dyes upon the minute forms of life, bacterial and protozoal, which we have been discussing ?"

The answer to this question is that considering the whole range of dyes, some dyes possess destructive action upon bacteria and upon protozoa, while others do not in the dilutions used, so that speaking generally there are some dyes which exert a more selective action than others. When we consider the dyes possessing this destructive action they fall into the following three groups :—

1. Those which act upon both bacteria and protozoa.
2. Those which act upon some bacteria more than upon others.
3. Those which act in great dilution upon protozoa and in much less dilution upon bacteria.

Thus auramine and crystal violet act upon both bacteria and upon protozoa, and the oxazine dyes, such as Nile blue, Meldola's blue, act much more intensely upon protozoa than upon bacteria.

Again, there are other dyes which act more powerfully upon the gram positive organisms like staphylococci, B. Diphtheriæ, and even upon anthrax spores than upon the gram negative organisms, such as B. Coli and B. Typhosus.

Even amongst the gram negative group—B. Coli, B. Lactis, B. Paratyphosus A and B., B. Enteritidis (Gaertner), B. Dysenteriæ (Shiga) and B. Dysenteriæ (Flexner)—even amongst these there is a certain amount of gradation. Thus we have often noticed that B. Dysenteriæ (Shiga) and (Flexner) are killed more easily than B. Coli and B. Lactis, whereas B. Typhosus occupies an intermediate position.

In our opinion, for this reason B. Typhosus is not a suitable organism for the routine testing of disinfectants to the exclusion

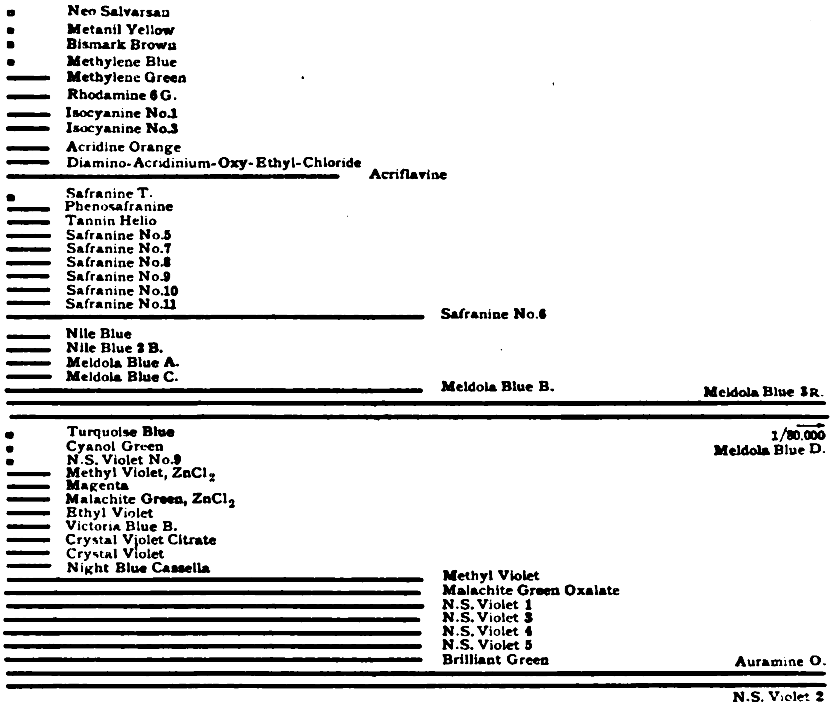


Fig. 1.—Chart showing relative lethal power of dyes (on paramoecia).

of other organisms. We wish to emphasise this point since it emerges quite clearly from this work and since it is the organism usually employed in the standardisation of disinfectants and antiseptics in the Rideal-Walker method. It cannot be too clearly stated that it is *not* the most resistant of the common organisms for which disinfectants are often employed.

A curious fact emerges in regard to B. Phlei—the Timothy Grass Bacillus. This is an acid fast bacillus, resembling in some respects the tubercle bacillus. Presumably like the tubercle bacillus it has a lipoid envelope and so it ought to resist fairly well the action of many of the dyes, yet in our results it was often killed.

Are there any reasons which may account for this apparent difference or selective action of dyes upon bacteria and upon protozoa? Some years ago one of us found that a culture of a unicellular plant—the protococcus—could be purified and separated from associated bacteria by immersing the mixed culture in a certain dye solution over a period of days, after which on sub-culturing into a suitable nutrient fluid a pure culture of the protococcus resulted.

Previously all other methods had failed to yield a pure culture of the protococcus. In this experiment the protococcus had resisted the action of the dye which was present in sufficient strength to kill the bacteria.

Here the stout cellulose wall of the protococcus had prevented the penetration of the dye to the more vital part of the cell, which still showed unchanged chlorophyll, albeit the cell had entered into a spore stage during the time of immersion in the dye.

Resistance to penetration of the dye is therefore a factor which sometimes helps to explain poor antiseptic action, and it may explain some of those cases in which naked protozoa are killed more readily than bacteria possessing a cell wall. It is not, however, the only factor, for in some cases protozoa may be immersed in a dye and actual vital staining of the cell may occur without death resulting, as in the case of methylene blue. It is probable, therefore, that the dye has some action either upon the medium in which the bacteria or protozoa are present, or more likely, that the dye has a chemical or physical action, or both, upon the organism acted upon. In view of the staining which occurs, most often of the nucleus of a protozoon, and sometimes of the protoplasm, it is probable

that an actual chemical action takes place leading to a destruction or alteration of the chemical components of the living cell.

These chemical relationships have been dealt with more fully in the first part of the paper, and it is obvious that selective action occurs in the coal tar dyes within limits which may be wide in some cases, narrow in others.

One fact, however, emerges fairly clearly, and that is that selective action in the dyes is not confined so much to individuals as to broad classes of similar infective agents, and that within these classes selective action of a more restricted type is possible within narrow limits.

This fact is not confined to dyes. In the case of Salvarsan the drug may act not only upon the spirochaeta pallida of syphilis but upon other spirochaetae, such as Spirochaeta Pertenuis of Yaws, and even upon Spirilla, as shown by its surprising effect upon the Spirillum met with in Vincent's Angina.

A similar fact apparently holds good in regard to Bayer 205 since this can act not only upon the Trypanosome of sleeping sickness, T. Gambiense, but upon T. equiperdum (rats), T. Brucei, T. Equinum and T. Rhodesiense.

In our earlier work we used paramœcia largely for purposes of convenience, and ease of observation, and to enable us to run quickly through the list of dyes with the object of detecting those having any protozoal action at all. Having done this we ascertained the effect upon other protozoa, *e.g.* amoeba, and upon Trypanosomes, causing Trypanosomiasis and death in mice.

The difficulty of observing Trypanosomes is very much greater and the eye-strain is more serious than in the case of Paramœcia and it would have been a laborious task to have examined all our dyes good, bad or indifferent with this infective agent.

We tried the effect, however, of two of our most active dyes, Auramine and Nile Blue, separately, and in varying dilutions, upon Trypanosomes freshly obtained by bleeding a mouse infected with T. Venezuelense.

A most interesting fact emerged from this observation, *e.g.*, that within 15 minutes a dilution of 1/20,000 of Auramine, or 1/20,000 of Nile Blue A was sufficient to cause death to all the Trypanosomes in the film; whereas control films kept under the same conditions showed great activity at the expiration of even 30 minutes. These results coincided with the dilutions and times in our Paramœcium work.

Somewhat similar results had formerly been obtained with another flagellate, Euglena.

Accordingly, we believe that the results obtained with Paramœcia can be translated into terms of Trypanosomes, and we have no doubt but that dyes which will kill the former will kill the latter in the same dilutions and within the same time. A recognition of this fact should expedite very considerably future research on Trypanosomiasis.

As it is, we have been led by means of our work on Paramœcia to the discovery of a dye which we know will kill Trypanosomes within 15 minutes in a dilution of 1/20,000, *in vitro.*

The comparison of this dye with the results quoted by Wenyon in the case of Bayer 205 is proceeding.

The comparison between paramœcia and higher forms such as the filariæ is not quite so close, but even here we were able to obtain some resemblance. We have examined the action of the dye on the minute worms or filariæ present in a man suffering from this infection, and we found that Auramine again killed the filariæ in five minutes in a dilution of 1/4,000, and in 20 minutes in a dilution of 1/8,000 when mixed with the patient's blood.

If you will consider the bactericidal properties of the dyes as dealt with in the earlier part of the paper, and consider them in conjunction with these results, you will not fail to notice the selective action of certain dyes.

Sewage.

The possibilities arising out of this differential or selective action are extremely great also, with regard to soil problems and the purifications of sewage, and we will consider these before proceeding to the purely medical aspects.

This selective action may well be considered first in regard to a comparatively simple problem which has occurred in the partial or selective sterilisation of sewage, undergoing aeration in tanks.

There are many methods of sewage purification to-day, but probably one of the best and simplest is that in which the raw sewage is run into a tank and the whole

of it kept constantly aerated by agitation or by forcing air through it. The raw sewage flows in at one end of the tank, and the purified sewage flows from the other end after passing through a zone where settling occurs; or if the tank is a circular one there may be an outer settling zone not agitated.

As the sewage settles in this quiet zone a clear supernatant liquor runs off at the top and a loose open sludge settles at the bottom. Usually the tank should work so that the sludge settles to occupy only 10·15% of volume of the tank—the remaining 85%-90% of supernatant liquor being run away as purified effluent in the case of "fill and draw," or in the case of the continuous process complete displacement of the sewage in the tank should be effected within 10 hours.

Sometimes the sludge "bulks," and instead of settling to 10% or 15% of the total volume, it may not settle to more than 40%-80% of the tank; thus limiting the amount of clear effluent for discharge in the 24 hours.

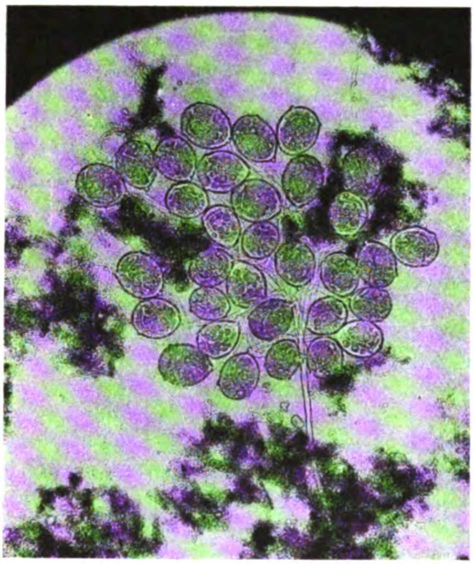


FIG. 2.—Protozoa present in Sewage Sludge. (Magnification approx. 100).

At the time of bulking it has been noticed by other observers and confirmed by us that protozoa are exceptionally numerous. They may interfere with the normal purification in two ways:—

(*a*) By ingesting the bacteria supposed to be responsible for the purification and preventing full multiplication.

(*b*) By forming a meshwork with their stalks and filaments on which smaller particles may settle.

The problem, therefore, was to ascertain what the effect of the removal of the protozoa would be without interfering with the normal working of the bacteria; *e.g.*, to effect a selective sterilisation of the sludge. The protozoa we met with most frequently in our examination of sludge were carchæsium, vorticella, and paramœcia.

We had ascertained that one of our dyes—Nile blue A—had a poor bactericidal action (1 in 2,000), but a powerful lethal action on protozoa (1 in 20,000).

Accordingly, we tried the effect of a 1 in 20,000 dilution of Nile blue A on sludge and found that most of the protozoa were killed within 15 minutes.

Nile blue not being obtainable in large quantities we investigated other members of the oxazine class of dyes including Meldola's blue and found the behaviour of this dyestuff was practically the same as Nile blue, but through the courtesy of the British Dyestuffs Corporation, Ltd., we were able to get a Meldola blue which would act in a dilution of 1 in 40,000 within 15 minutes, and we were supplied with quantities of this for trial. At this stage we were put in touch, through the Ministry of Health, with Mr. Bolton, of the Bury Sewage Works. By his courtesy and help we were enabled to try the effect of this dye on a tank which had been "bulking" very badly. Subsequent chemical investigation of the effluent has been conducted by Mr. Bolton and his assistant, Mr. Scott, to whom we are indebted for results which we have expressed in graph form.

Sewage Expt. No. 1. Steps were taken to remove the supernatant liquor from a 40,000 gallons tank of sewage leaving 3,600 gallons of sludge to be differentially sterilised. Ten pounds of Meldola's blue were dissolved in 40 gallons of hot water and added in 20 gallon amounts. Before and during mixing the sludge was agitated to ensure rapid mixing.

Before the dye was added numerous carchæsia and vorticella were present in an active condition, but an immediate examination made as soon as the dye was well mixed with sludge (15 minutes) showed these protozoa to be deeply stained and dead.

The concentration in this experiment was initially 1 in 3,600. Paramœcia were mixed experimentally with the dyed sludge at

this dilution and immediate death noted so that there was a considerable excess of dye. After 30 minutes the tank was diluted with fresh sewage to a concentration of 1 in 7,200. Examination again showed Carchaesia dead and deeply stained, there being no motion ciliary or contractile. After a further hour the tank was filled up with sewage and allowed to stand overnight and aerated at a dilution of 1 in 40,000, after which it was worked at its full capacity of 87,000 gallons of sewage treated per day, with the results indicated on the accompanying graphs, in regard to bulking albuminoid ammonia estimations, oxygen absorbed, purification. The exhausted dye liquor at a dilution of 1 in 40,000 was still able to kill test paramœcia within 1½ hours.

Sewage Expt. No. 2 (on same tank). Before this experiment was carried out, the contents of the tank were bulking very badly; although one foot of sludge had regularly been removed, the bulking was in no way checked.

At the time of the experiment the percentage bulking was as high as 80% and the amount of sludge treated was 10,000 gallons. As 10,000 gallons represented 100,000 lbs., 5lbs. of dye added would give a dilution of 1 in 20,000. The dye was dissolved prior to addition to the tank.

When the dye was added the contents of the tank were well agitated. After an interval of about 10 minutes, a fair sample was taken from the tank and examined for protozoa. The protozoa were not killed, although the forms were affected. At this point it was decided to add more dye, and 2½lbs. more were added to the tank. Again, after agitation, a fair sample was taken, and it was found that the protozoa were not killed as quickly as desired. An additional 2½lbs. of dye were added, and as before a sample was taken after about 10 minutes agitation. This showed that the protozoa were killed.

In this experiment it was noticed that the dye solution was exhausted almost as soon as it entered the tank. This was probably due to sewage having come in from a tannery and the dye was probably precipitated by the tannin.

This would account for the relatively longer time required to produce effective sterilisation in this experiment, together with the greater amount of sludge acted upon.

The tank was filled up and aerated overnight, but it was found on aeration that the blue colour reappeared, and this would again indicate some chemical action of sewage on the dye in this experiment.

Subsequent examinations on the same day and the day following showed no living protozoa, but numerous stained forms.

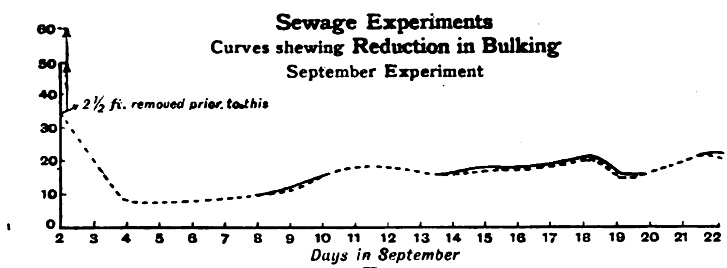


FIG. 3.

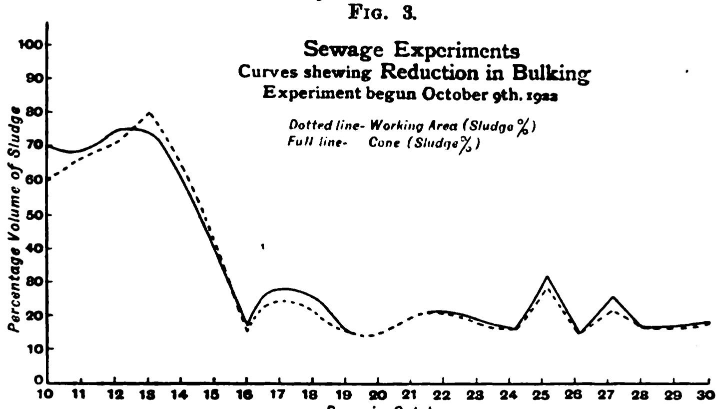


FIG. 4

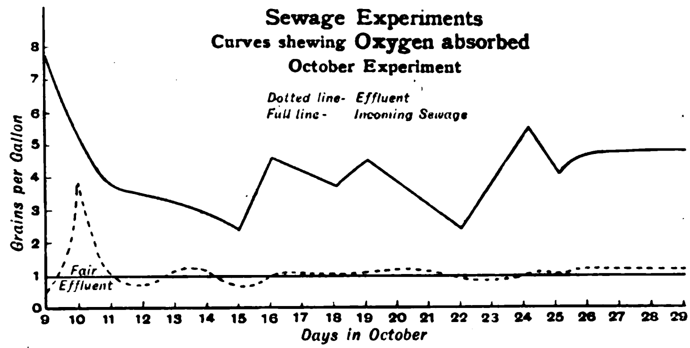


FIG. 5

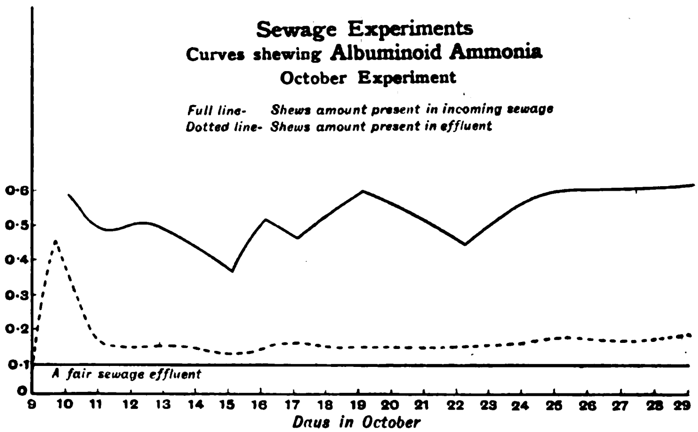


FIG. 6.

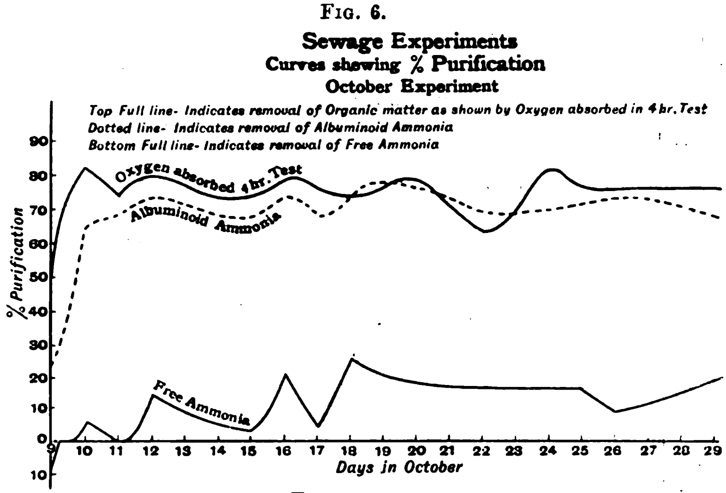


FIG. 7.

Graphs are submitted showing effects on bulking, etc.

GRAPH 1. September Experiment. Reduction in bulking.

Before the experiment was commenced, bulking was up to 60 per cent. $2\frac{1}{2}$ feet of the sludge was removed on the day of experiment, corresponding to 25 per cent., bringing the bulking down to 35 per cent.

Within two days of addition of the dye with the tank working at its full capacity, the bulking had dropped to 8 per cent., and it remained at 8-20 per cent. for eighteen days after the experiment commenced. The mere removal of sludge does not usually stop the bulking tendency of the sludge. (Fig. 3.)

GRAPH 2. September Experiment. Oxygen absorbed.

The oxygen absorbed figure showed an increase for three days following addition of

dye; but on the fourth day it approached the normal figure for a satisfactory effluent; and from the sixth day to the twentieth day was even better than the average sewage effluent figure.

During this time the incoming sewage gave high figures of oxygen absorbed, so that a considerable degree of purification occurred.

GRAPH 3. September Experiment. Albuminoid ammonia.

Immediately after the experiment the albuminoid ammonia figure rose until two days after, when a rapid fall towards a normal figure occurred. This decline was interrupted a week after the experiment, when the incoming sewage also showed a considerable increase. After this, the figure approached normal and about 10-11 days after, was within normal limits.

The second experiment showed better figures for albuminoid ammonia.

GRAPH 4. September Experiment. Percentage Purification of Sewage.

Within three days the purification as shown by a four hour test of absorption of oxygen (e.g. test of removal of organic matter) had risen to 60 per cent., ultimately rising to 85 per cent. within ten days, with the tank now working at its full capacity.

GRAPH 5. October Experiment. Reduction in bulking.

Before this experiment the sludge had been showing a daily increase of 30—40 per cent. in bulk, and large amounts had had to be removed to attempt to restrain the bulking.

Within six days of the addition of dye, the sludge had fallen from 70 per cent. to a normal working limit of 15 per cent., and continued within 15 per cent. to 30 per cent. for a fortnight or longer.

With such a large amount of dead protozoal material in the tank, it was obvious that amounts would have to be removed, and accordingly quantities of this dead material were removed from time to time, but the quantities removed would not in themselves have accounted for a mechanical diminution in bulking, for similar quantities had been removed prior to the experiment, and the tank sludge still remained prior to the addition of dye round about 80 per cent. even with these removals. (Fig. 4.)

GRAPH 6. October Experiment. Oxygen absorbed figure.

After two days the oxygen absorbed figure reached normal limits and continued so for 18 days or longer. (Fig. 5.)

GRAPH 7. October Experiment. Albuminoid Ammonia.

This chart shows the albuminoid figures. A high incoming albuminoid content is converted into almost normal figures. The degree of purification is affected for two days, after which it is practically normal. (Fig. 6.)

GRAPH 8. October Experiment. Percentage Purification.

Shows 72 per cent. purification of albuminoid ammonia within three days; purification as represented by oxygen absorbed shows 81 per cent. within one day of addition of dye. (Fig. 7.)

Since these experiments have been undertaken, we have found a further derivative of the Meldola Blue class which kills paramœcia practically instantly in a dilution of 1 in 80,000, and within 2½ hours in a dilution of 1 in 160,000.

From these experiments it will be seen that as regards the bulking factor this can easily be remedied by the treatment with dyes of the oxazine class, and experiments are in hand to ascertain the exact conditions for obtaining the biggest decrease in bulking coupled with the smallest interference with the rate of purification in the tank.

AGRICULTURE.

These experiments have introduced us to one of the applications of selective sterilisation. Agriculture will, no doubt, make many uses of this method in the future.

Experiments have been described to effect a partial sterilisation of soil, and agricultural experts, such as Dr. Russell, of the Rothamsted Experimental Station, have held the opinion for some years that considerable improvements in agriculture could be effected if the soil could be partially sterilised or freed from protozoa without harming the nitrifying bacteria. The experiments quoted related to the use of toluene and arsenious acid as the partial sterilising agent, but no great measure of success was obtained by these substances. Our results would indicate that much more positive results could be obtained by using certain of the dyes of the oxazine class. This is a field which we have been unable to explore, but undoubtedly it offers great possibilities to the agricultural chemist and bacteriologist.

MEDICAL.

Let us now turn to a consideration of the requirements which must be met by substances which it is proposed to use in the treatment of infections present in man and in animals.

1. *Selective Action*. If possible there should be a strong chemical affinity between the drug used and the parasite to be destroyed. It is probable that the number of such substances is fairly considerable, and the selective action will be, therefore,

largely a relative condition, and will not be absolute, so that the action in one type of protozoon may be held to give a rough indication on others not too widely different. It is probable also, that such substances will bear some relationship to the tissues in which the parasite resides, but this relationship should only be slight.

2. *Toxicity.* The poisonous action of the drug on human tissues should be slight, if any, and *no specialised tissue should be damaged.*

3. *Antiseptic action* is related to selective action, but does not necessarily coincide with it. Thus Methylene Blue stains but does so without killing certain protozoa. The destructive effect of such a drug, on an infective agent, should be great and complete destruction of the parasite in all phases of its life cycle should be effected. The ratio $\frac{\textit{curative}}{\textit{tolerated dose}}$ should be a small fraction of unity.

4. *Efficient penetration.* The drug should dialyse rapidly and easily so that great penetration should be possible of tissues with poor blood supplies, *e.g.*, cartilage, fibrous tissue, cornea.

5. *Administration.*

(*a*) Continuous administration should be possible if the drug is non-toxic and non-cumulative, so that it should be able to be administered preferably by mouth, and should not be altered by the digestive juices.

(*b*) Intermittent. Large doses should be capable of being given intravenously or subcutaneously if only intermittent administration is desired.

6. *Elimination* should be gradual but complete, and the kidneys should not be damaged in this process.

7. *Coincident action.* It should not interfere with the normal processes concerned in natural immunity.

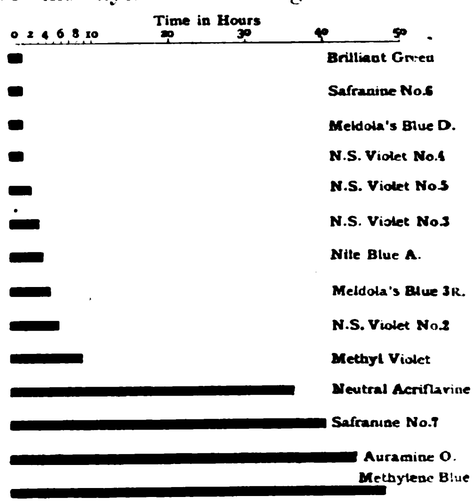
8. *Standardisation.* This should be possible by simple means, and similar products prepared in different laboratories should yield identical physiological results.

Experimentally, we must first endeavour to obtain dyes for further observation which have a selective action on any given parasite in very high dilutions.

Having obtained a number of these, the subsequent work resolves itself into observing the effect of such powerful dyes upon higher animals and subsequently upon human beings. The problem, therefore, is not only the provision of antiseptic substances, but the discovery of substances which, while exerting antiseptic action on the parasite, are not harmful to the host in whose tissues that parasite resides. Toxicity.

In other words can we get synthetic substances which the more highly specialised human tissues can resist, but which the lower simpler forms of life cannot, just as we obtained a dye which the protococcus can resist, but which bacteria cannot? (In using the word dye we include all those compounds which may properly be elaborated arising from a study of the synthetic dyes.)

Such action is relative. The time factor as well as the concentration factor varies in regard to the action of the same dye on widely dissimilar animals. A consideration of the time of action of, say, auramine on protozoa like paramoecia, and on fishes will illustrate this point. We decided to try the action of some of the dyes on small goldfishes when



FISHES: Immersion in Dye Solutions
1/20,000
FIG. 8.

immersed in a solution of dye (1 in 20,000), in which dilution we knew that paramoecia could only live about 15 minutes. In brilliant green the fishes only lived for 90 minutes, but in auramine they lived for 18 hours.

Mice. Subcutaneous injections of solutions of dyes have been given to mice of known weight (20-24 grams). The dyes which have been given are :—

Auramine O. 0.244 grams per kilo, dead in 30 minutes. 0.127 grams per kilo, lived.

Meldola's blue D. 0.252 grams per kilo. Died in 15 minutes.
Methylene blue. 0.252 grams per kilo. Died next day.
Neutral acriflavine. 0.25 grams per kilo. Died next day.
Nile blue A. 0.253 grams per kilo. Lived.
Safranine No. 7. 0.25 grams per kilo. Died next day.

Guinea Pig. A guinea pig was given 5 c.c. of a 1 in 200 solution of auramine by mouth three times a day without ill effects for four days.

Mice were fed for 14 days on bread soaked in 1/200 solution of auramine. The fæces became coloured with the dye, but the animals lived and apparently suffered no ill effects, for they were alive six months afterwards.

Rabbits. Intravenous injections of auramine O and of Nile blue were given to rabbits. In the case of Nile blue an immediate toxic action was shown, the animal careering violently round the cage and apparently losing all sense of control.

The auramine rabbit showed no change at all and lived for months afterwards.

Dogs. By the courtesy of the Physiological Department of Manchester University and with the help of Dr. Macswiney and Dr. Mucklow, experiments were tried to show the effect on the heart and on respiration. Tracings of the blood pressure were taken in the case of dogs to which dyes were given intravenously into the jugular vein. Kymograph tracings with a cannula in the external carotid artery were taken, the animal being anæsthetised. The results are shown on the accompanying slides.

It is impossible to show the whole record in view of its length, but typical portions are shown.

These results show, I think, that Nile blue would be a dangerous drug to give intravenously, although for local action it might be used in small doses.

In the case of auramine there is, I think, no evidence of any such toxic action in the dose as given, and I believe that it ought to be possible to use this drug for intravenous medication in trypanosomiasis.

CLINICAL FINDINGS.

Specimens of auramine were submitted to Dr. Dan Mackenzie, F.R.C.S. (Ed.), for trial in ear work, and he writes regarding the general impression created by its use: "I have no doubt as to the utility of auramine in chronic suppuration of the middle ear. It has a cleansing, even, you might say, an astringent effect upon the infected mucous surfaces; it reduces discharge and encourages healing. I have used it mostly combined with an equal quantity of alcohol. (S.V.R.)"

Specimens of auramine were also submitted to Mr. Wilson Hey, F.R.C.S., for trial as an antiseptic for preparing the skin prior to operation, and he writes:—

"I have used the spirituous solution of auramine as supplied by you on ten or eleven cases. It has been applied to the skin in each case on the operating table. All the cases in which this was done have healed up by first intention. I consider that it is just as efficacious as iodine or picric acid solutions in alcohol. Perhaps more so, but I have no means of deciding."

CONCLUSION.

Let us now turn for a few minutes, in conclusion, to the present state of preventive medicine, and glance at the further outlook.

The group of diseases due to some infective agent is responsible directly or indirectly for nine-tenths of the human suffering and misery resulting from diseased conditions. Thus the greater portion of heart and lung diseases are bacterial in origin; rheumatism is due to a toxin derived from organisms growing may be in remote organs; peritonitis, pleurisy, meningitis present a definite bacteriology.

It is on this group that we have focussed our energies during the past four or five years. The three main classes of the groups are:—(1) Bacterial infections. (2) Parasitic—including protozoal—invasions. (3) Filtrable viruses. With the exception of the mechanical effects resulting from the larger parasitic infections—such as the worms infecting man—these three classes have one feature in common. By their biological activity in the host—man—they produce toxins which are able to cause serious damage to tissues, and even general death of organs. The nature and intensity of this intoxication is dependent upon the character of the organisms producing it, upon their number, and upon the resistance of the body to the infection.

We have known the tissue of a paratyphoid patient so affected by the growth of paratyphoid bacilli during an attack of the disease that anti-substances were detected in his blood in a dilution of 1 in 500,000.

Similarly diphtheria bacilli when grown in broth may produce a toxin so virulent that 1/25 part of a drop or 1/500 cc.. can kill a guinea pig weighing 500 grams; that is to say, a toxin can be prepared so powerful in action that it can cause death to a mass of living tissue 250,000 times heavier than itself. These examples could be multiplied.

Since the discovery of the compound microscope, infective disease has become a clearly defined field. Infective agents have not only been discovered, but have been proved to be the cause of the disease. There are diseases in which as yet no known organism has been found which satisfies Koch's postulates. There are also a number of diseases in which it has been shown experimentally that these agents are too small to be seen by the microscope. The larger number of diseases, however, have a definite accepted cause which is visible to the microscope, and about whose life history most of the facts are known. The diseases not italicised have no definite specific treatment available. This list shows the diseases of bacterial origin, where again those not italicised have no specific agent available for treatment. In all, some 50 specific infective diseases are important. Of these the causative agent is not yet discovered in twelve. Of the remaining 38, a partially successful curative agent is available in ten. There are thus 28 diseases in which the causative agent is known, in which no specific treatment is available and to these must be added the twelve infective diseases of unknown origin, since they are known to be infective, making a total of 40.

Truly precise diagnosis awaits specific treatment.

Epid. C.S. Meningitis. Erysipelas. Glanders. *Gonorrhœa.* Leprosy. Malta fever. Paratyphoid fever. Plague. Pneumonia. Puerperal fever. "Rag pickers" disease. *Ringworm. Septic infections of surfaces, joints, etc. Tetanus.* Tuberculosis. Typhoid. Whooping cough.

Unknown Infective Agents.—Chickenpox. Dengue. Influenza. German measles. Measles. Mumps. Scarlet fever. Smallpox. Rocky Mountains fever. Trench fever. Typhus and Mexican fever.

Filtrable Viruses.—Acute anterior poliomyelitis. Foot and mouth disease, Phelbotomus fever. (?) Rabies. Yellow fever.

Parasitic Infections.

(a) Protozoal. — *Amœbic dysentery.* Ciliate dysentery. Kala azar. *Malaria.* Oriental sore. Relapsing fever. Sleeping sickness. *Syphilis. Yaws.*

(b) Metazoal.—Worms; tapeworms, filariæ, flukes. Insects. (*"Itch" parasite.*)

Bacterial and Fungal Infections.—*Actinomycosis. Anthrax.* Cholera. *Diphtheria.* Dysentery.

This summary is of necessity brief—a complete survey of the present state of preventive medicine would be far beyond the scope of this paper—but it is sufficient to shew that there is a vast field of virgin soil to be tilled with regard to the production of specifics to counteract the ravages of infectious disease.

In our work on the relationship between chemical constitution and antiseptic action in the synthetic dyes we have attempted to investigate one small corner of the field. Whether we have succeeded in establishing a relationship between chemical constitution and antiseptic action in the synthetic dyes, or whether we have failed, does not influence the importance of the subject. In all probability compounds will be found which possess greater antiseptic properties than any we have studied, but we feel that the information we have gleaned as a result of our investigation regarding the influence of various chemical groups and groupings, will be of great assistance in the synthesis of bodies which will possess even greater antiseptic action. We have fully realised the necessity of coupling the antiseptic properties of a body with its physiological properties, and we have always realised that the experiments "in vitro" with bacteria in the laboratory can but be a rough guide to their efficiency in the treatment of disease, but we have maintained that if a chemical substance fails to kill bacteria in the simple conditions of a test tube, it is useless to consider it for use amongst the complex ramifications of the human system. When, however, decided antiseptic properties have been manifested in vitro, then we have endeavoured to investigate fully the physiological properties with a view to finding out the advisability of using the substance on human subjects. In such physiological investigations the way is long and weary—difficulties arise all along the path and progress is very slow almost to the point of despair. But out of it all comes a glimmer of light which gives hope

for the future. In auramine we have a substance with remarkable antiseptic properties. It has been used successfully by eminent surgeons, at our request, in the surgery of the ear and nose, and for the treatment of skin operations, with excellent results and no objectionable side effects. We have had promising results with it in experiments on dogs, mice, guinea pigs, rabbits and fishes, and so far there seems no reason at all why it should not be used intravenously or in other ways without untoward results.

Our contribution to this work has been small. An enormous amount of experimental work has boiled down to a few salient facts and a little more knowledge regarding antiseptic action. We hope that in our very inadequate paper to-night we have given you some idea of the magnitude of the field awaiting investigation and venture to hope that our efforts may ultimately do something towards the alleviation of human suffering and the amelioration of the conditions of human life.

[A demonstration was given by means of a micro-projection apparatus kindly lent by Messrs. W. Watson & Sons.

The light from an arc lamp passing 20 amperes was condensed, the heat rays absorbed by means of a ferrous sulphate solution, and passed through a spot lens showing a dark ground effect.

Living paramoecia were first projected on the screen, and their motility demonstrated. A similar culture was then mixed with a solution of Meldola blue giving an ultimate dilution of 1/40,000. The paramoecia became affected almost instantly, and within three minutes were quite dead. A similar culture was put up with Neo-salvarsan so as to obtain an ultimate dilution of 1/200, and the paramoecia were seen to be living.]

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Results Obtained with Bacteria

TABLE I.

Dilutions of 1/500.

+ Indicates that organism lived. 0 That it was inhibited.

Dyestuff.	*B. phlæi.*	*Staphylococcus.*	*Streptococcus.*	*B. diphtheriæ*	*B. subtilis.*	*B. anthracis.*	*B. acidi lactici.*	*B. coli.*	*B. dysenteriæ* (Flexner).	*B. enteritidis* (Gaertner).	*B. paratyphosus* A.	*B. paratyphosus* B.	*B. dysenteriæ* (Shiga).	*B. typhosus.*
Acridine orange ..	0	+	0	0	0	0	0	0	0	+	0	+	0	0
Azo geranine ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Blue black	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Benzo fast helio ..	0	+	0	0	+	+	+	+	+	+	+	+	+	+
Chrysophenine ..	0	+	0	0	+	+	+	+	+	+	+	+	+	+
Congo corinth ..	0	0	0	0	0	+	+	+	+	+	+	+	+	+
Congo orange ..	+	+	0	+	+	+	+	+	+	+	+	+	+	+
Congo red	+	+	0	+	+	+	+	+	+	+	+	+	+	+
Congo rubine ..	+	+	0	+	+	+	+	+	+	+	+	+	+	+
Crystal violet ..	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dianol black ..	0	+	+	+	+	+	+	+	+	+	+	+	+	+
Dianol blue	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Dianol brown ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Dianol fast yellow	0	+	0	+	+	+	+	+	+	+	+	+	+	+
Dianol violet ..	+	+	0	+	+	+	+	+	+	+	+	+	+	+
Eosine	0	+	0	0	+	0	+	+	+	+	+	+	+	+
Fast blue 2B ..	0	+	+	+	+	+	+	+	+	+	+	+	+	+
Formyl violet ..	+	0	0	0	0	+	+	+	+	+	+	+	+	+
Indigo carmine ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Methylene blue ..	0	0	0	0	0	0	0	+	0	+	+	+	0	+
Nile blue A ..	0	0	0	0	0	+	+	+	+	+	+	+	+	+
Pinks A, BK & R	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ +
Rhodamine G ..	0	0	0	0	0	+	0	0	+	+	+	+	+	+
Rhodamine 6G ..	0	0	0	0	0	+	0	0	0	+	+	+	+	+
Rhodamine B ..	0	+	0 +	0	+	+	+	+	+	+	+	+	+	+
Rosaphenine 10B	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Safranine T ..	0	0	0	0	0	0	+	0	0	+	+	0	0	0
Soluble blue	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Sloaline	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Tannin helio ..	0	0	0	0	0	+	0	0	0	0	0	0	0	0
Tartrazine	+	+	+	0	+	+	+	+	+	+	+	+	+	+
Toluidine blue ..	0	0	0	0	0 +	0 +	+	+	0	+	+	+	0	+
Trypan blue ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Turquoise blue ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Vale yellow	+	+	+	0	+	+	+	+	+	+	+	+	+	+
Acid green 1 ..	+	+	0	0	+	+	+	+	+	+	+	+	+	+
Acid green 2 ..	+	+	+	0	+	+	+	+	+	+	+	+	+	+
Neutral red	0	0	0	0	0	+	+	+	+	+	+	+	+	+

ADDITIONAL DYE DERIVATIVES.

The reference numbers refer to the tables of formulae given in the paper. Dilutions of 1/500.

Reference No.	B. Phloei.	Staphylococcus.	Streptococcus.	B. Diphtheriae.	B. Subtilis.	B. Anthracis.	B. acidi Lactici.	B. Coli.	B. Dysenteriae (Flexner).	B. Enteritidis (Gaertner).	B. Paratyphosus A.	B. Paratyphosus B.	B. Dysenteriae (Shiga)	B. Typhosus.
Violet N.S. 1	0	0	0	0	0	0	+	+	+	+	+	+	0	+
,, N.S. 2	0	0	0	0	0	0	0	0	0	+	0	+	0	+
,, N.S. 3	0	0	0	0	0	0	0	0	0	+	+	+	0	0
,, N.S. 4	0	0	0	0	0	0	+	+	+	+	+	+	0	+
,, N.S. 5	0	0	0	0	0	0	0	0	0	0	0	+	0	0
,, N.S. 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
,, N.S. 7	0													
,, N.S. 8			0	0	+	0	+	+	+	+	+	+	+	+
,, N.S. 9	0	+		0	+	+	+		+	+	+	+	+	+
Safranine 1	+	+		+	+	+	+		+	+	+	+	+	+
,, 2	+	+		+	+	+	+		+	+	+	+	+	+
,, 3	+	+		0	+	+	+		+	+	+	+	+	+
,, 4	+	+		+	+	+	+		+	+	+	+	+	+
,, 5	0	0		0	0	+	0		0	0	0	0	0	0
,, 6	0	0		0	0	0	0		0	0	0	0	0	0
,, 7	0	0		0	0	0	+		0	+	+	+	0	0
,, 8	0	0		0	0	0	0		0	+	+	+	0	0
,, 9	0	0		0	0	+	0		0	0	0	0	0	0
,, 10	0	0		0	0	0	0		0	0	0	0	0	0
,, 11	0	0		0	0	0	0		0	0	0	0	0	0
Brilliant Green		0	0	0		0	+	.0						+
Diamino acridinium oxyethyl chloride		0	0	0		0	0	0						0
Neutral Acriflavine		0	0	0		0	0	0						0
Neptune Green	0	+		+	0	+	+		+	+	+	+	+	+
Azo 1	0	+	0	0	+	+	+	+	+	+	+	+	+	+
Cyanol Green ..	0	0		0	0	0	+		+	+	0	+	+	+
Lissamine Green ..	0	0		0	0	0	+		+	+	+	+	0	0
Night Blue Cassella	0	0		0	0	0	+		0	+	+	+	+	+

TABLE 2.

Dilutions of 1/1000.

Dyestuffs.	*B. phlei.*	*Staphylococcus.*	*Streptococcus.*	*B. diphtheriæ.*	*B. subtilis.*	*B. anthracis.*	*B. acidi lactici.*	*B. coli.*	*B. dysenteriæ* (Flexner).	*B. enteritidis* (Gaertner).	*B. paratyphosus A.*	*B. paratyphosus B.*	*B. dysenteriæ* (Shiga).	*B. typhosus*
Auramine O.. ..	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Auramine G ..	0	0	0	0	0	0	+	0	0	0	0	+	0	0
Azo geranine ..	+ +	+	+ +	+	+	+	+	+	+	+	+	+	+	+
Blue black	+0	+	+	+	+	+	+	+	+	+	+	+	+	+
Benzo fast helio ..	+ +	+	+	+	+	+	+	+	+	+	+	+	+	+
Chrysoidine ..	00	+	+	+	+	+	0	0	0	0	0	0	0	0
Chrysophenine ..	+0	+	+	+	+	+	+	+	+	+	+	+	+	+
Chlorantine brown ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Congo corinth ..	+ +	+	+ +	+	+	+	+	+	+	+	+	+	+	+
Congo orange ..	+ +	+	+	+	+	+	+	+	+	+	+	+	+	+
Congo red	+ +	+	+ +	+	+	+	+	+	+	+	+	+	+	+
Congo rubine ..	+ +	+	+	+	+	+	+	+	+	+	+	+	+	+
Chrysamine	00	00	00	00	+ +	00	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
Crystal yellow ..	+0	+	+	0	0	0	0+	+ +	0+	0+	0+	0+	0+	0+
Crystal violet ..	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diaminogen blue 2B	+00	+	+	+	+	+	+	+	+	+	+	+	+	+
Dianol black ..	+ +	+	+	+	+	+	+	+	+	+	+	+	+	+
Dianol blue 2B ..	+ +	+	+	+	+	+	+	+	+	+	+	+	+	+
Dianol brown LF ..	+ +	+	+	+	+	+	+	+	+	+	+	+	+	+
Dianol fast claret ..	+	+	+	0	0	0	+	+	+	+	+	+	+	+
Dianol fast yellow ..	+ +	+	+	+	+	+	+	+	+	+	+	+	+	+
Dianol violet ..	+0+	+	+	+	+	+	+	+	+	+	+	+	+	+
Eosine	+0+	+	+	+	+	+	+	+	+	+	+	+	+	+
Eta chrome black ..	00	0+	0	0	0	+	+	+	0	+	+	+	0	0
Fast blue 2B ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Formyl violet ..	+ +	+	0	0	+	+	+	+	+	+	+	+	+	+
Flavine	000	000	000	00	+ +0	+ +0	0	0	0	0	0	0	0	0
Indigo carmine ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Indine blue	0	0	+	+	+	+	+	+	+	+	+	+	+	+
Induline	0	+	0	0	+	+	+	+	+	+	+	+	+	+
Lissamine yellow ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Meldola's blue ..	0	0	0	0	0	+	+	+	+	+	+	+	0	+
Metanil yellow ..	+0	+	+	0	+	+	+	+	+	+	+	+	+	+
Methyl violet Z ..	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Methylene blue ..	0+0	+	0+0	0	0	+	+	+	0	0	+ +	00	0	+ +
Methylene violet ..	00	0	0	0	0	+	0	+	0	0	0	0	0	0
Methylene green ..	0	0	0	0	0	0	+	+	0	0	+	+	+	+
Nile blue A ..	0	0	0	0	0	0	+	+	+	+	+	+	+	+
Nile blue 2B ..	0	0	0	0	0	0	+	+	+	+	+	+	+	+
Neutral red	0	0	0	0	0	+	+	+	+	+	+	+	+	+
Nigrosine	+	+	0	0	0	+	+	+	+	+	+	+	+	+
Night blue	0	0	0	0	0	+	+	+	+	+	+	+	+	+
Phenosafranine ..	+0	00	0	0	0	0+	0	0	0	0	0	0	0	0
Pink A	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pink BK	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pink R	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pyramine orange ..	0	0	0	0	0	+	+	+	+	+	+	+	+	+
Rhodamine G ..	+00	0	+0	0+	0	+	0+	+	+	+	+	+	+	+
Rhodamine 6G ..	00	0	0	0	0	+	+	+	0	+	0	+	0	+
Rhodamine B ..	+ +	+	+	0	+	+	+	+	+	+	+	+	+	+
Rosaphenine 10B ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Safranine T ..	0	0	0	0	0	0	+	+	0	0	+	+	0	+
Soluble blue.. ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Sloaline No. 2 ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Tannin helio ..	00	00	00	00	0+	+	0	0	0	0	0	0	0	0
Tartrazine	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Thional yellow ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Toluidine blue ..	00	0	0	0	0+	0+	+	+	0	0	0	+	0	0
Trypan blue ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Turquoise blue ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Vale yellow	+	+	+	+	+	+	+	+	+	+	+	+	+	+
An acid green 1 ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
An acid green 2 ..	00	+	0	0	+ +	+	+	+	+	+	+	+	+	+
Malachite green hydrochloride	0	0	0	0	0	0	+0	+0	0	0	0	+0	0	+0
Malachite green $ZnCl_2$	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malachite green oxalate	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malachite green citrate	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crystal violet hydrochloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crystal violet arsenite														
Crystal violet citrate.	0	0	0	0	0	+	+	+	+	+	+	+	0	0
Crystal violet tartrate	0	0	0	0	0	0	+	+	0	0	0	+	0	0
Crystal violet oxalate	0	0	0	0	0	0	+	+	0	+	+	+	0	0
Methyl violet 10B ..	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Methyl violet 2B ..	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Methyl violet $ZnCl_2$	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Erio floxine 6B ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+

ADDITIONAL DYE DERIVATIVES.

The reference numbers refer to the tables of formulae given in the paper. Dilutions of 1/1,000.

Reference No.	B. Phlœi.	Staphylococcus.	Streptococcus.	B. Diphtheriae.	B. Subtilis.	B. Anthracis.	B. acidi lactici	B. Coli.	B. Dysenteriae (Flexner).	B. Enteritidis (Gaertner)	B. Paratyphosus A.	B. Paratyphosus B	B. Dysenteriae (Shiga).	B. Typhosus.
Violet N.S. 1	0	0	0	0	0	0	+	+	+	+	+	+	+	+
,, N.S. 2	0	0	0	0	0	0	0	+	0	+	0	+	0	+
,, N.S. 3	0	0	0	0	0		+	+	0	+	+	+	0	+
,, N.S. 4	0	0		0	0	0	+		+0	+	+	+	+	+
,, N.S. 5	0	0	0	0	0	0	0	0	0	+	+	+	0	0
,, N.S. 6	0	0	0	0	0	0	0	0	0	+	0	+	0	0
,, N.S. 7	+	+		+	+	+	+	+	+	+	+	+	+	+
,, N.S. 8	0	+	0	0	+	0	+	+	+	+		+	+	+
,, N.S. 9	0	+		0	+	+	+		+	+	+	+	+	+
Safranine 1	+	+		+	+	+	+		+	+	+	+	+	+
,, 2	+	+		+	+	+	+		+	+	+	+	+	+
,, 3	+	+		0	+	+	+		+	+	+	+	+	+
,, 4	+	+		+	+	+	+		+	+	+	+	+	+
,, 5	0	0		0	0	+	+		0	+	0	+	0	+
,, 6	0	0		0	0	0	0		0	0	0	0	0	0
,, 7	0	0		0	0	+	+		+	+	+	+	0	+
,, 8	0	0		0	0	0	+		0	+	+	+	0	0
,, 9	0	0		0	0	+	0		0	0	0	0	0	0
,, 10	0	0		0	0	0	0		0	0	0	0	0	0
,, 11	0	0		0	0	0	0		0	0	0	0	0	0
Brilliant Green		0	0	0		0	+	0						+
Diamino acridinium oxyethyl chloride		0	0	0		0	0	0						0
Neutral Acriflavine		0	0	0		0	0	0						0
Neptune Green	0	+		+	+	+	+		+	+	+	+	+	+
Azo 1	0	+	0	+	+	+	+		+	+	+	+	+	+
Cyanol Green ..	0	0	0	0	0	+	+		+	+	+	+	+	+
Lissamine Green ..	0	0		0	0	0	+		+	+	+	+	0	+
Night Blue Cassella	0	0		0	0	+	+		+	+	+	+	+	+

TABLE 3.

Dilutions of 1/2000.

Dyestuffs.	*B. phlœi.*	*Staphylococcus*	*Streptococcus.*	*B. diphtheriæ.*	*B. subtilis.*	*B. anthracis.*	*B. acidi lactici*	*B. coli.*	*B. dysenteriæ* (Flexner.)	*B. enteritidis* (Gaertner).	*B. paratyphosus A.*	*B. paratyphosus B.*	*B. dysenteriæ* (Shiga).	*B. typhosus.*
Auramine O.. ..	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Auramine G.. ..	0	0	0	0	+	0	+	0	0	0	0	+	0	0
Chrysoidine	+	+	+	+	+	+	+	0	0	+	+	+	0	+
Chrysamine	0	+	0	0	+	+	+	+	+	+	+	+	+	+
Crystal yellow ..	+	+	+	0	0	0	+	+	+	+	+	+	+	+
Crystal violet ..	0	0	0	0	0	0	+	0	0	0	0	+	0	0
Era chrome black ..	0	+	+	+	+	+	+	+	+	+	+	+	+	+
Flavine	0	0	0	0	+0	+0	0	0	0	0	0	0	0	0
Meldola's blue ..	+	0	0	+	+	+	+	+	+	+	+	+	+	+
Methyl violet $ZnCl_2$	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Methylene blue ..	0	+	0	0	0	+	+	+	+	+	+	+	+	+
Nile blue A ..	0	+	0	0	+	+	+	+	+	+	+	+	+	+
Nile blue 2B ..	0	+	0	0	+	+	+	+	+	+	+	+	+	+
Neutral red	0	0	0	0	0	+	+	+	+	+	+	+	+	+
Night blue	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Phenosafranine ..	0	0	0	0	0	+	+	+	+	+	+	+	+	+
Rhodamine 6G ..	0	0	0	0	0	+	+	+	+	+	+	+	+	+
Safranine T ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Tannin helio ..	0	0	0	0	0	+	+	+	+	+	+	+	+	+
Toluidine blue ..	0	0	0	0	0	+	+	+	+	+	+	+	+	+
Malachite green ..	0	0	0	0	0	0	+	+	+	+	+	+	+	+
Induline	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Nigrosine	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Magenta	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Additional Dye Derivatives.

The reference numbers refer to the tables of formulæ given in the paper. Dilution of 1/2,000.

Reference No.	B. Phlœi.	Staphylococcus	Streptococcus	B. Diphtheriae	B. Subtilis.	B. Anthracis.	B. acidi lactici	B. Coli.	B. Dysenteriae (Flexner).	B. Enteritidis (Gaertner).	B. Paratyphosus A.	B. Paratyphosus B.	B. Dysenteriae (Shiga).	B. Typhosus.
Violet N.S.1 ..	0	0	0	0	0	0	+	+	+	+	+	+	+	+
„ N.S.2 ..	0	0	0	0	0	0	0	+	0	+	+	+	0	+
„ N.S.3 ..	0	0	0	0	0	0	+	+	+	+	+	+	0	+
„ N.S.4 ..	+	+		0	0	0	+		+	+	+	+	+	+
„ N.S.5 ..	0	0	0	0	0	0	+	+	0	+	+	+	0	+
„ N.S.6 ..	0	0	0	0	0	0	0	0	0	+	+	+	0	+
„ N.S.7 ..	+	+	0	+	+	+	+	+	+	+	+	+	+	+
„ N.S.8 ..	0	+	0	0	+	+	+	+	+	+	+	+	+	+
„ N.S.9 ..	0	+		0	+	+	+		+	+	+	+	+	+
Safranine 1. ..	+	+		+	+	+	+		+	+	+	+	+	+
„ 2. ..	+	+		+	+	+	+		+	+	+	+	+	+
„ 3. ..	+	+		0	+	+	+		+	+	+	+	+	+
„ 4. ..	+	+		+	+	+	+		+	+	+	+	+	+
„ 5. ..	0	0		0	0	+	+		+	+	+	+	0	+
„ 6. ..	0	0		0	0	+	0		0	+	+	+	0	0
„ 7. ..	0	0		0	0	+	+		+	+	+	+	0	+
„ 8. ..	0	0		0	0	0	+		0	+	+	+	0	0
„ 9. ..	0	0		0	0	+	+		0	+	+	+	0	+
„ 10. ..	0	0		0	0	0	0		0	0	0	0	0	0
„ 11. ..	0	0		0	0	0	0		0	0	0	0	0	0
Brilliant Green ..		0	0	0		0	+	+						+
Diamino acridinium oxyethyl chloride ..		0	0	0		0	0	0						0
Neutral Acriflavine ..		0	0	0		0	0	0						+
Neptune Green ..	0	+		+	+	+	+		+	+	+	+	+	+
Azo 1 ..	0	+	0	+	+	+	+	+	+	+	+	+	+	+
Isocyanine 1 ..	0	+		0	0	0	+		0	+	+	+	0	+
Isocyanine 2 ..	0	+		0	0	+	+		0	+	+	+	0	+
Cyanol Green ..	0	0		0	0	+	+		+	+	+	+	+	+
Lissamine Green..	0	+		0	+	0	+		+	+	+	+	0	+
Night Blue Cassella ..	0	0		0	0	+	+		+	+	+	+	+	+

TABLE 4.

Dilutions of 1/5000.

Dyestuffs.	B. Phlœi.	Staphylococcus	Streptococcus.	B. Diphtheriae.	B Subtilis	B Anthracis.	B. Acidi lactici	B. Coli	B. Dysenteriae. (Flexner).	B. Enteritidis. (Gaertner).	B. Paratyphosus A.	B. Paratyphosus B.	B Dysenteriae (Shiga)	B. Typhosus.
Auramine O.. ..	0	0	0	0	0	0	0	+	0	0	0	0	0	0
Auramine G.. ..	0	0	0	0	+	+	+	+0+	0	0	0	0	0	0
Auramine O-$ZnCl_2$ ..	0	0	0	0	0	0	+	0	0	0	0	0	0	0
Chrysamine	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Era chrome black ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Induline	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Nigrosine	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Night blue	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Methyl Violet-$ZnCl_2$	0	0	0	0	0	0	+	+	0	0	0	+	0	0
Crystal violet ..	+	0	0	0	0	0	+	+	+	0	+	+	0	0

RESULTS WITH PARAMŒCIA.

Dyestuff.	1/200.		1/2000.		1/20,000.	
	Observation.		Observation.		Observation.	
	Immediate.	After 15 mins.	Immediate.	After 15 mins.	Immediate.	After 15 mins.
Nile Blue A ..	Dead.	Dead.	Dead.	Dead.	Forms affected Flagellates dead.	Moribund After 30 mins. chiefly dead.
Crystal Violet ..	Dead.	Dead.	Dead.	Dead.	Active.	Dead or moribund.
Dianol Violet ..	Active.	No dead forms Many active.	—	—	—	—
Nile Blue BB ..	Dead.	Dead.	Dead.	Dead.	Some dead. Flagellates. dead.	Some dead. some living. All dead after 24 hours.
Erio floxine ..	Active.	Active after 14 hours.	—	—	—	—
Formyl Violet ..	Active.	Active.	—	—	—	—
Magenta ..	Dead.	Dead.	Active.	Dead.	Active.	Dead or moribund. All dead after 24 hours.
Methyl Violet $ZnCl_2$ ..	Dead.	Dead.	Dead.	Dead.	Active.	Living. Flagellates dead.
Malachite Green $ZnCl_2$ ..	Dead.	Dead.	Dead	Dead.	Active	Some living. Dead after 24 hours.
Methylene Blue..	Dead.	Dead.	Active.	Active.	—	—
Acid Green ..	Active.	Active after 14 hours.	—	—	—	—
Phenosafranine ..	Dead.	Dead.	Dead.	Dead.	Active	Active.
Ethyl Violet ..	Dead.	Dead.	Dead.	Dead.	Affected.	Dead or moribund. Stained.
Dianol fast claret	Active.	Chiefly active.	—	—	—	—
Chlorantine brown	Active.	Active.	—	—	—	—
Rhodamine. G ..	Active.	Active.	—	—	—	—
Auramine O. ..	Dead.	Dead.	Dead.	Dead.	Moribund.	All dead.
Pyramine orange	Active.	Active. (stained).	—	—	—	—
Lissamine yellow	Active.	Active.	—	—	—	—
Congo red ..	Active.	Active.	—	—	—	—
Pink BK. ..	Active.	Active.	—	—	—	—
Victoria Blue B.	Dead.	Dead.	Dead.	Dead.	Active.	Active.
Rosaphenine 10B	Active.	Active.	—	—	—	—
Rhodamine B. ..	Active.	Active.	—	—	—	—
Trypan blue ..	Active.	Active.	—	—	—	—
Metanil yellow	Dead.	Dead.	Active.	Dead.	Active.	Active.
Azo geranine ..	Active.	Active.	—	-	-	—
Crystal Violet citrate ..	Active.	Dead.	Active.	Dead	Living.	Living..
Meldola's blue ..	Dead.	Dead.	Dead.	Dead.	Living.	Dead.
Tannin helio ..	Dead.	Dead.	Dead.	Dead.	Living.	Living.
Indigo carmine..	Living.	Living.	—	—	—	—
Turquoise blue ..	Dead.	Dead.	Active.	Some dead.	—	—
Acridine orange..	Dead.	Dead.	Dead.	Dead.	Active.	Active.
Bismarck brown	Dead.	Dead.	Active.	Active.	—	—
Rhodamine 6G..	Dead.	Dead.	Dead.	Dead.	Active.	Active.
Malachite green oxalate ..	Dead.	Dead	Dead.	Dead.	Moribund.	Dead.
Safranine T. ..	Dead.	Dead.	Active.	Active.	—	—
Methylene green .	Dead.	Dead.	Active.	Dead	Active.	Active.
Acriflavine ..	Dead.	Dead.	Dead.	Dead.	Active.	Active after 24 hours.
Neosalvarsan ..	Active.	Active.	Active	Active.	—	—

RESULTS WITH PARAMŒCIA.

Dye.	1/200. Observation.		1/2,000. Observation.		1/20,000. Observation.		1/40,000. Observation.	
	Immediate.	Within 15 mins.	Immediate.	Within 15 mins.	Immediate.	Within 15 mins.	Immediate.	Within 15 mins.
New Series Violet No. 1	Dead.	Dead.	Dead.	Dead.	Dead.	Dead.	Active.	Active (Forms affected.)
New Series Violet No. 2	Dead.	Dead.	Dead.	Dead.	Active.	Dead.	Active.	Dead.
	Dilution	1/80,000.	Immediate	observation	Active.			
			Within 15	minutes	Active.			
New Series Violet No 3	Dead.	Dead.	Dead.	Dead.	Active.	Dead.	Active.	Active.
New Series Violet No. 4	Dead.	Dead.	Dead.	Dead.	Active.	Dead.	Active.	Active.
New Series Violet No. 5	Dead.	Dead.	Dead.	Dead.	Active.	Dead.	Active.	Active.
New Series P.B.V. No. 7 ..	Active.	Active.						
New Series. C.F.G. No. 8 ..	Active.	Active.						
New Series No. 9 ..	Active.	Dead.	Active.	Active.				
Safranine No. 1 ..	Active.	Active.						
Safranine No. 2 ..	Active.	Active.						
Safranine No. 3 ..	Active.	Active.						
Safranine No. 4 ..	Active.	Active.						
Safranine No. 5 ..	Dead.	Dead.	Dead.	Dead.	Active.	Active.		
Safranine No. 6 ..			Dead.	Dead.	Active.	Dead.	Active.	Active.
Safranine No. 7 ..			Dead.	Dead.	Active.	Active (Dead after 4 hours.)		
Safranine No. 8 ..	Insoluble.		Active.	Dead.	Active.	Active.		
Safranine No. 9 ..	Dead.	Dead.	Active.	Dead.	Active.	Active. 90% dead in 45 mins		
Safranine No. 10 ..	Dead.	Dead.	Dead.	Dead.	Active.	Active.		
Safranine No. 11 ..	Dead.	Dead.	Dead.	Dead.	Active.	Active. Dead in 45 mins.		
Isocyanine No. 1 ..	Insoluble.		Active.	Dead.	Active.	Active.	Active.	Active.
Isocyanine No. 2 ..	Insoluble.		Active.	Active. Dye not soluble.				
Isocyanine No 3 ..	Insoluble.		Active.	Dead.	Active.	Active.		
Naphthol Green ..	Insoluble.		Active.	Active.				
Neptune Green ..	Active.	Active.						
Night Blue Cassella	Dead.	Dead.	Dead.	Dead.	Active.	Active.		
Cyanol Green 6 G. ..	Active.	Dead.	Active.	Active.				
Lissamine Green B.	Active.	Active.						
Brilliant Green ..	Dead.	Dead.	Dead.	Dead.	Active.	Dead.	Active.	Active.
Methyl Violet ..	Dead.	Dead.	Dead.	Dead.	Active.	Dead.	Active.	Active.
Diamino-Acridinium-Oxyethyl-chloride	Dead.	Dead.	Dead.	Dead.	Active.	Active.		
Neutral Acriflavine ..	Dead.	Dead.	Dead.	Dead.	Active.	Active.		
Quinine Hydrochloride	Dead.	Dead.	Active.	Dead.	Active,	Active,		
Meldola's Blue D. ..			Dead.	Dead.	Active.	Dead.	Active.	Dead.
Meldola's Blue D. ..	Dilution	1/80,000.	Immediate	observation	—Active.			
			Within 15	minutes	—Dead.			
" "	Dilution	1/160,000.	Immediate	observation	—Active.			
			Within 15	minutes	Active.	Dead in 2½	hours.	
Indine Blue ..					Active.	Dead.		
Auramine O & Indine Blue ..							Active.	Dead.
Auramine O & Indine Blue ..	Dilution	1/80,000.	Immediate	observation	—Active.			
			Within 15	minutes	—Active.			
" "	Dilution	1/160,000	Immediate	observation	—Active.			
			Within 15	minutes	—Active.			
	1/10	00.						
Auramine O.	(Dead.	Dead.)	Dead.	Dead.	Active.	Dead.	Active.	Dead.
		1/80,000.	Immediate	observation	—Active			
			Within 15	minutes.	—Active.			

DISCUSSION.

THE CHAIRMAN (Sir Humphry Rolleston) expressed the cordial thanks of the meeting to Mr. Fairbrother and Dr. Renshaw for having let them into the secret of what they had been doing in the past at Manchester, and making the audience "wise"—to use an American term—in this important subject. He then invited questions or discussion.

Mr. W. C. PECK asked whether the authors had any idea as to the exact chemical action of the dyes on particular bacteria. What actually happened between the organic compounds and the substances of which the bacteria were composed? Had they made any researches similar to those made by Rogers and Muir on the action against *B. lepra* of sodium salts of the muriatic and chaulmoogric acids? These observers seemed to think that the acids formed a coating around the bacillus, because evidence of fatty acids had been found in the bacteria.

Dr. J. B. Christopherson, C.B.E., F.R.C.P., said that his own particular work had been on bilharzia. His impression was in bilharzia a non-organic compound acted in such a way that the sheet or covering of the ovum or worm was permeable to the drug, and the drug passed inside and actually killed the bilharzia.

Mr. A. M. Cheyne asked whether the authors did not think the action was due to the fact that the substance passed through the sheath of the bacteria and killed the protoplasm proper, which was found to be stained. The dye substance penetrated the envelope and combined with the protoplasmic substance within.

Dr. Renshaw, in reply, said that with regard to Mr. Peck's question about the leprosy bacillus, a curious fact emerged from their work on the timothy grass bacillus, which was an acid-fast bacillus, just like the leprosy bacillus, and had also apparently a lipoid envelope similar to the leprosy and the tubercle bacillus—namely, that many dyes got through that lipoid envelope to all appearance, and the timothy grass bacillus was killed off in many of the experiments they did. It was not necessarily a combination of the fatty acids of the bacteria with the dye, because in the oxazines one got a differential tat stain, and these were poor bactericidal agents. As to whether there was any chemical action between the protoplasm of the bacillus or the paramœcia and the dye, it was probable that the basic dye affected the nucleus, and that would indicate that it was probably an acid group in the nucleus which was capable of combining with the basic part of the dye to form a salt. If the protoplasm were treated with acids, like citric or tartaric acid, granular change occurred in the protoplasm, which one did not observe with many of the dyes. With regard to bilharzia, it would be necessary to have drugs or dyes of great penetrative powers to get through the outer membrane of the ovum.

Mr. Fairbrother said that he had little to add to the remarks of his colleague. It was an undoubted fact that the acid dyes stained the protoplasm, but the fact of the staining of the protoplasm would not appear to have any great antiseptic action, because in the whole series of dyes studied no acid dyes showed any antiseptic action at all. The organisms always lived in these acid dyes. Therefore, although there seemed to be some sort of physical affinity of the protoplasm with the acid dye stuffs it did not appear to be that affinity which settled the antiseptic question.

On the motion of the Chairman, a vote of thanks was accorded to Mr. Fairbrother and Dr. Renshaw, and the meeting terminated.

GENERAL NOTES.

New process for making Wool Fur.—According to the United States Consul-General at Melbourne, a newly invented process whereby certain kinds of fleece not well adapted to spinning can be manufactured into a rich fur-like material, which is supposed to present a valuable hygienic advantage over skin furs for clothing because the material is mounted on a wool foundation, is reported from Perth, Western Australia. The inventor claims that this material has an excellent appearance and that it is suitable for all purposes for which fur is utilized and for clothing where the utmost warmth, the least weight, and the maximum of protection are demanded.

Making Rain by Aeroplane.—According to *The Engineer*, the United States Army Air Service has "attacked and successfully solved" the problem of precipitating rain by means of aeroplanes. Professor Bancroft, of Cornell University, has been conducting experiments during the past two months on the dissipation of fogs over aerodromes, and is now able to cause precipitation of rain clouds by flying an aeroplane 500 feet or so above a cloud, and causing it to scatter with its propeller electrically charged sand. The theory is that this electrical charge diminishes the surface tension of the drops of moisture and thus facilitates coalescence and condensation.

MEETINGS OF THE SOCIETY.

Ordinary Meetings.

Wednesday at 8 p.m., except where otherwise stated :—

March 21.—F. W. Edridge-Green, C.B.E., M.D., F.R.C.S., "Some Curious Phenomena of Vision and their Practical Importance." Professor E. H. Starling, C.M.G., M.D., Sc.D., F.R.S., will preside.

April 11 (at 4.30 p.m).—Edward Parnell, "The Resources and Trade of Sarawak."

April 18 (at 4.30 p.m.).—Hal Williams, M.I.Mech.E., M.I.E.E., M.I.Struct.E., "Modern Abattoir Practice and Methods of Slaughtering." W. Phené Neal, Alderman of the City of London, late Chairman of the Cattle Markets Committee of the Corporation, will preside.

April 25 (at 4.30 p.m.).—Conference on "The Milk Question." Short papers will be read as follows :—(1) Professor R. Stenhouse Williams, M.B., B.Sc., L.R.C.P.

and S.E., D.P.H., "The Arguments for Maintaining an Open Market for Fresh Milk;" (2) PROFESSOR J. CECIL DRUMMOND, D.Sc., F.I.C., "Changes in the Digestibility and Nutritive Value of Milk induced by Heating;" (3) S. S. ZILVA, Ph.D., D.Sc., F.I.C., "The Effect of Heat on some Physiological Principles in Milk." A Demonstration of some of the Chemical Changes in Milk on Heating to various Temperatures will be given by CAPTAIN JOHN GOLDING, D.S.O., F.I.C. and MRS. A. T. R. MATTICK. M.Sc.

MAY 2.—MAURICE DRAKE, "The Fourteenth Century Revolution in Glass Painting."

MAY 9.—WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Recent Developments in Surface Combustion."

MAY 16.—

MAY 30 (at 4.30 p.m.).—A. J. SEWELL, "The History and Development of the Perambulator and Invalid Carriage."

INDIAN SECTION.

Friday afternoons.

APRIL 6, at 4 p.m.—GEOFFREY ROTHE CLARKE, C.S.I., O.B.E., I.C.S., Director-General Posts and Telegraphs, India, "Postal and Telegraph Work in India." LORD MONTAGU OF BEAULIEU, K.C.I.E., C.S.I., will preside.

JUNE 1, at 4.30 p.m.—AUSTIN KENDALL, I.C.S., rtd., "The Indian Section of the British Empire Exhibition, 1924."

JUNE 15, at 4,30 p.m.—SIR JOHN H. MARSHALL, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture.)

DOMINIONS AND COLONIES AND INDIAN SECTIONS. (Joint Meetings.)

Tuesday or Friday afternoons at 4.30 o'clock.

APRIL 20.—SIR RICHARD A. S. REDMAYNE, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S., "The Base Metal Resources of the British Empire."

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

J. E. SEARS, C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards, "Accurate Length Measurement." Three Lectures. March 5, 12, 19.

SYLLABUS.

LECTURE III.—*March* 19. Measurement of spheres and cylinders; Hertz compression; elasticity of "fit"; snap gauges; form gauges; horizontal projector; screw gauges; diameters; pitch; angle; thread form; vertical projector; internal measurements; plaster casts; measurement of gears.

E. KILBURN SCOTT, Assoc., M.Inst.C.E., M.I.E.E., "The Fixation of Nitrogen." Three Lectures. April 9. 16, 23.

HOWARD LECTURES.

Monday evenings at 8 o'clock.

STANLEY S. COOK, "Recent Improvement in Steam Turbines." Three Lectures. April 30, May 7, 14.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, MARCH 19 .. Geographical Society, Lowther Lodge, Kensington Gore, S.W., 5 p.m. Col. M. N. Macleod, Squadron-Leader Laws and Major Griffiths, "Recent Developments in Air Photography."

British Architects, Royal Institute of, 9, Conduit Street, W., 8 p.m. Mr. G. E. S. Streatfeild, "The Hammersmith Housing Scheme."

East India Association, Caxton Hall, Westminster, S.W., 3.30 p.m. Dr. G. Slater, "Protection for India."

Textile Institute (London Section). Mr. W. Bailey, "The Production of Cotton Yarns."

Mechanical Engineers, Institution of, Storey's Gate, Westminster, S.W., 7 p.m. (Graduates' Section). Mr. R. C. Bond, "The Walschaert Locomotive Valve-Gear."

TUESDAY, MARCH 20 .. Statistical Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.15 p.m. Mr. A. W. Flux, International Statistical Comparisons.

Royal Institution, Albemarle Street, W., 3 p.m. Dr. C. G. Seligman, "Rain Makers and Divine Kings of the Nile Valley." (Lecture II.).

Civil Engineers, Institution of, Great George Street, S.W., 6 p.m.

Transport, Institute of, at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, S.W., 5.30 p.m. Messrs. F. Bushrod and J. F. S. Tyler, "Modernisation of Passenger Railway Stations."

Oriental Studies, School of, London Institution, Finsbury Circus, E.C., 5 p.m. Sheik Abd El Razek, "The Study in Europe of Moslem Civilisation."

Roman Studies, Society for the Promotion of, at the Society of Antiquaries, Burlington House, Piccadilly, W., 4.30 p.m. 1. Mr. A. H. Smith, "A New Military Diploma (Tabula Nonestae Missionis) from Egypt." 2. Dr. R. E. M. Wheeler (a) "The Romans in Pembrokeshire." (b) "Two Roman Ivories from Caerleon."

Marine Engineers, Institute of, 85, The Minories, Tower Hill, E., 6.30 p.m. Mr. J. Lamb, "Operation of Marine Oil Engines, Cylinders and Pistons."

Architecture Club, Grosvenor House, Upper Grosvenor Street, W., 5 p.m. Prof. W. Rothenstein, "Is Architecture the Mother of the Arts?"

University of London, University College, Gower Street, W.C., 5.15 p.m. Prof. E. T. Whittaker, "Electric Fields in Atomic Physics." (Lecture IV.).

At King's College, Strand, W.C., 5.30 p.m. Prof. H. W. Carr, "Physical Causality and Modern Science." (Lecture V.).

Photographic Society, 35, Russell Square, W.C., 7 p.m. Mr. W. F. A. Ermen, "The Preparation of Metal and its Homologues."

Production Engineers, Institution of, at the Engineers' Club, Coventry Street, W., 7.30 p.m. Mr. J. D. Scaife, "Ball and Roller Bearing Manufacture."

Victoria League, 296, Vauxhall Bridge Road, S.W., 4.30 p.m. The Earl of Ronaldshay, "Lands of the Thunderbolt: a Narrative of Travel in Sikhim, Chumbi and Bhutan."

WEDNESDAY, MARCH 21 .. Naval Architects, Institution of, at the Royal United Service Institution, Whitehall, S.W., 11 a.m. Annual Meeting. 1. Address by the President (The Duke of Northumberland). 2. Sir Eustace T. d'Eyncourt and J. H. Narbeth, "A Proposed Aircraft Carrying Mail Steamer." 3. Sir John E. Thornycroft and Lieut. Bremner, "Coastal Motor Boats in War-time."

3 p.m., Mr. A. C. F. Henderson, "Remarks on some of the Present Day Problems in the Design of Ships."

British Architects, Royal Institute of, 9, Conduit Street, W., 5 p.m. Lord Fumner of Ibstone, "The Public and the Architect."

Industrial League and Council, Caxton Hall, Westminster, S.W., 7.30 p.m. Mr. T. E. Naylor, "The Fallacy of Low Wages."

Meteorological Society, 49, Cromwell Road, S.W., 7.30 p.m. Mr. G. M. B. Dobson, "The Characteristics of the Atmosphere up to 200 km. as obtained from Observations of Meteors."

Microscopical Society, 20, Hanover Square, W., 7.30 p.m. 1. Mr. E. Hatchek, "The Standard Methods of Ultra-Microscopy." 2. Dr. A. C. Thaysen, "The Destruction of Cotton and other Fabrics by Bacteria, and the Importance of the Microscope in the Study of this Destruction."

Public Health, Royal Institute of, 37, Russell Square, W.C., 4 p.m. Dr. W. J. O'Donovan, "The Industrial Menace of Syphilis."

British Decorators, Institute of, Scarborough, 7.30 p.m. Mr. T. Peters, "A Visit to Italy by a Decorator who does some Landscape Painting," illustrated by sketches done there.

University of London, University College, Gower Street, W.C., 5 p.m. Mr. P. Leon, "The Theory of Beauty." (Lecture VI.).

At the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C., 5.15 p.m. Prof. M. Walker, "The Control of the Speed and Power Factor of Induction Motors."

THURSDAY, MARCH 22 .. Naval Architects, Institution of, at the Royal United Services Institution, Whitehall, S.W., 11 a.m. Annual Meeting continued. 1. The Hon. Sir Charles A. Parsons and Messrs. S. S. Cook and H. M. Duncan, "Mechanical Gearing." 2. Mr. W. Le Roy Emmett, "Electric Ship Propulsion."

3 p.m. Messrs. G. S. Baker and W. C. S. Wigley, "Model Screw Propeller Experiments with Mercantile Ship Forms."

8 p.m. Mr. K. C. Barnaby, "The Powering of Motor Ships."

Royal Society, Burlington House, Piccadilly, W., 4.30 p.m.

Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.

Royal Institution, Albemarle Street, W., 3 p.m. Lieut.-Col. E. F. Strange, "Japanese and Chinese Lacquer." (Lecture II.).

Optical Society, at the Imperial College of Science, South Kensington, S.W., 7.30 p.m. Dr. L. C. Martin, "Surveying and Nautical Instruments from a Historical Standpoint."

Mechanical Engineers, Institution of (Midland Branch), The University, Birmingham, 7.30 p.m. Mr. F. Somers, "The Manufacture of Forgings."

Child Study Society, 90, Buckingham Palace Road, S.W., 6 p.m. Dr. H. C. Miller, "The New Discipline."

Camera Club, 17, John Street, Adelphi, W.C., 8.15 p.m. Mr. T. Bell, "Portraiture."

Auctioneers and Estate Agents Institute, 34, Russell Square, W.C., 7.30 p.m. Mr. W. E. Fox, "Some Hints to Young Estate Agents."

University of London, University College, Gower Street, W.C., 5.30 p.m. Dr. A. Bugge, "The Viking Crusades and their bearing on British Industry." (Lecture II.).

At King's College, Strand, W.C., 5.30 p.m. Prince D. S. Mirsky, "Three Russian Poets, Puskin, Leskor and Blok." (Lecture III.).

Structural Engineers, Institution of, 296, Vauxhall Bridge Road, S.W., 7.30 p.m. Prof. A. J. S. Pippard, "A Method for the Direct Design of Frame Structures having Redundant Bracing."

Brewing Institute of (N.E. Section), Queen's Hotel, Leeds, 6.30 p.m. Mr. O. Overbeck, "Brewing Scents and Smells, and their Origin and Properties."

(Midland Section), Grand Hotel, Birmingham, 7 p.m. Mr. F. A. Smith, "The Season's Malt."

FRIDAY, MARCH 23 .. Engineering Inspection, Institution of, at the Royal Society of Arts, John Street, Adelphi, W.C., 7.30 p.m.

Naval Architects, Institution of, at the Royal United Service Institution, Whitehall, S.W., 11 a.m. 1. Prof. T. B. Abell, "The Behaviour of Stiffened Thin Plating under Water Pressure." 2. Dr. J. Montgomerie, "Further Experiments on Large Size Riveted Joints." 3. Mr. J. Anderson, "The Influence of Form upon the Stability and Propulsion of Passenger Ships."

3 p.m. 1. Mr. W. Thomson, "The Effect of Variations in Loading on Longitudinal Structural Stresses in Ships." 2. Mr. E. V. Telfer, "Graphical Trim Calculation and a Trim Nomogram."

Royal Institution, Albemarle Street, W., 9 p.m. Sir Ernest Rutherford, "Life History of an Alpha Particle from Radium."

Physical Society, at the Imperial College of Science, South Kensington, S.W., 5 p.m.

Engineers, Junior Institution of, 89, Victoria Street, S.W., 7.30 p.m. Mr. R. J. Siddall, "The History and Development of the Underground Railway."

SATURDAY, MARCH 24 .. Royal Institution, Albemarle Street, W., 3 p.m. Sir Ernest Rutherford, "Atomic Projectiles and their Properties." (Lecture VI.).

London County Council, at the Horniman Museum, Forest Hill, S.E., 3.30 p.m. Dr. W. A. Cunnington, "The Natural History of Lobsters and Prawns."

Journal of the Royal Society of Arts.

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FRIDAY, MARCH 23, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

NOTICES.

FIFTEENTH ORDINARY MEETING.

WEDNESDAY, MARCH 14th, 1923; THE RIGHT HON. LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Assinder, G. F., D.C.L., London.
Beit, Sir Otto, K.C.M.G., LL.D., London.
Gidney, C. W. A., Bhusaval, India.
Jain, Madan Mohan, Gwalior, Central India.
Marshall, Albert E., Baltimore, U.S.A.
Montgomery, George Hugh Alexander, B.C.L., K.C., Montreal, Canada.
Peterson, John Carlos Kennedy, C.I.E., Bombay, India.
Shank, Mrs. Edith Blanche, Coorg, South India.
Utley, Thomas, Liverpool.
Waring, Captain Harold, C.B.E., London.

The following candidates were duly elected Fellows of the Society:—

Huberich, Charles Henry, D.C.L., LL.D., The Hague, Netherlands.
Leonida, Ingenieur Dimitrie, Bucharest, Roumania.
Napier, William Joseph, Auckland, New Zealand.
Oakes, Edgar Stanley, Calcutta, India.
Thurston, Joseph Marshal, M.D., Richmond, Indiana, U.S.A.
Weiss, Carl W., New York, U.S.A.

A paper on "Industrial Arbitration" was read by SIR WILLIAM MACKENZIE, K.B.E., K.C.

The paper and discussion will be published in a subsequent number of the *Journal*.

DOMINIONS AND COLONIES AND INDIAN SECTIONS.

FRIDAY, MARCH 16th, 1923; EARL WINTERTON, M.P., Under Secretary of State for India, in the Chair.

A paper on "Recent Advances towards the Solution of the Leprosy Problem" was read by LIEUT.-COLONEL SIR LEONARD ROGERS, C.I.E., F.R.S., F.R.C.P., Physician and Lecturer, London School of Tropical Medicine.

The paper and discussion will be published in a subsequent number of the *Journal.*

CANTOR LECTURE.

On MONDAY EVENING, MARCH 19th, MR. J. E. SEARS, Junr., C.B.E., M.A., M.I.Mech.E., Superintendent of Metrology, National Physical Laboratory, and Deputy-Warden of the Standards, delivered the third and final lecture of his course on "Accurate Length Measurement."

On the motion of the Chairman, MR. A. S. NAPIER, M.Inst. C.E., a vote of thanks was accorded to MR. SEARS for his interesting course.

The lectures will be published in the *Journal* during the summer recess.

REPRINT OF CANTOR LECTURES.

The Cantor Lectures on "Brown Coals and Lignites," by WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, have been re-printed from the *Journal*, and the pamphlet (price 2*s.*) can be obtained on application to the Secretary, Royal Society of Arts, John Street, Adelphi, W.C. 2.

A full list of the lectures which have been re-printed and are still on sale can also be obtained on application.

LIST OF FELLOWS.

The new edition of the List of Fellows of the Society is now ready, and copies can be obtained on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.

TENTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 7TH, 1923.

SIR ROBERT A. HADFIELD, Bt., D.Sc., F.R.S. in the Chair.

The following paper was read:—

ELECTRICAL RESISTANCE FURNACES AND THEIR USES.

By CHAS. R. DARLING, A.R.C.S.I., F.Inst.P., F.I.C.

The large scale generation of electricity by hydro-electric or steam turbine installations, which enables electric power to be distributed at a low cost, has already resulted in the frequent replacement of low-power steam and other engines by the electric motor.

For the production of heat for general purposes, however, the substitution of electricity for fuel has not been on an extensive scale, particularly in countries like Britain, in which fuel is relatively cheap and water-power small in supply. One of the lines of development in this direction is provided by the electrical resistance furnace, which, in its various forms, is finding a continuously extending application in industrial processes. Starting as a special laboratory appliance a little over twenty years ago, the resistance furnace has acquired such importance that a description of the various forms and their uses appears to be desirable. The present paper will be confined to furnaces in which an enclosure is heated by electricity, as the inclusion of other types—such as the carborundum furnace—would lead to an undue extension of the matter to be dealt with in the time available.

ADVANTAGES OF ELECTRICAL RESISTANCE FURNACES.

The heating of an enclosure by fuel of any kind results in the formation of gaseous products, which must be led into a flue. These products, moreover, must escape at a temperature at least equal to that of the heated surface, and as the heat thus escaping (on the small scale) cannot be utilised, a large proportion of the total heat developed is wasted. In the resistance furnace, on the contrary, no products of combustion are formed, and by lagging the enclosure with a suitable heat-insulating material the escape of heat may be reduced to a very small amount. Owing to this fact a small enclosure can be heated more economically by electricity than by gas, although the cost of 1 therm (100,000 B.Th.U.) produced by electricity at 1d. per unit is three times as great as that involved by burning gas at 10d. per therm. When the enclosure is large enough to allow of the gas being burnt internally, so that the exterior may be lagged, the thermal costs may then be in favour of gas. Internal firing, however, is often objectionable owing to the impurities existing in the gas, whereas an electrically heated enclosure possesses a clean atmosphere, and is better suited to the heating of delicate articles which might be damaged by contact with impure gas. Instances in which coal or oil may be regarded as competitors are rare. A great advantage of the resistance furnace is the accuracy and ease with which it may be controlled so as to maintain a steady temperature. A suitable rheostat in series with the furnace enables any desired temperature, within the limits of the resistance material, to be kept steady for any period; and in this respect the resistance furnace is greatly superior to fuel furnaces. Precise temperature regulation is often essential to the complete success of laboratory and industrial operations.

Skilled labour is not necessary in the working of electrical resistance furnaces, as the controlling operation merely consists in moving a slider along a rheostat. Labour charges are, therefore, no greater than in the case of gas furnaces. The absence of products of combustion enables them to be used in any position in a workshop or laboratory, and by the use of efficient lagging the exteriors of the furnaces remain cool, so that the atmosphere of the room is not unduly heated. It is these advantages which have led to the popularity of the furnaces now to be described in detail.

METAL-WOUND FURNACES.

The first form of resistance furnace to come into general use in the laboratory was introduced by Herœus, in 1902. It consisted of a porcelain refractory tube, round which a strip of platinum foil was wound in spiral form. This tube was suitably lagged to minimise radiation losses, and under favourable conditions could be brought to 1,500°C. One of the drawbacks

to its use was that if placed directly across the power mains arcing was liable to occur, resulting in the burning out of the winding. A winding of platinum having a resistance of 1 ohm at 0°C has a resistance approximately five times as great at 1,300°C, and hence, if used across 100 volt. mains, the current immediately on starting would be 100 amperes, which would fall to 20 amps. at 1,300°. It was, therefore necessary to use an external resistance in the circuit to reduce the current at starting, and gradually to cut out this resistance as the temperature rose—an operation which wasted both time and current. In spite of this defect, the platinum-wound furnace was found to be preferable to gas heating for many purposes, and is still used for temperatures between 1,000° C and 1,500° C. The high cost of platinum restricts the size of these furnaces to dimensions which, whilst sufficient for many laboratory experiments, are too small for industrial processes. Any material present in the refractory tube which attacks the platinum causes the winding to fuse, and it is inadvisable to use tubes of silica, and many forms of fireclay, for this reason. Alundum is now usually employed for the tubes of platinum-wound furnaces, and is probably the best of the materials at present available.

As many important tests, such as those connected with the hardening of carbon steel, are conducted below 1,000°C, attention was directed in many quarters to the use of base-metal windings. Nickel, which melts about 1,450°C, and does not readily oxidize below 1,000°C, was successfully used by many workers, and nickel-wound furnaces, with porcelain tubes, were placed on the market in this country in 1906. This furnace, like its predecessor, required outside regulation by a resistance on starting to prevent fusion of the winding, and after some time the nickel became brittle and broke. The cost of renewing the winding —usually in the form of wire—was, however, comparatively small, and this served greatly to popularise the use of resistance furnaces. An early trouble was the cracking of the porcelain tubes owing to sudden changes of temperature, which was overcome by the adoption of tubes of vitrified silica.

The chief factor in the great development since attained by metal-wound furnaces, was the introduction of nickel-chromium alloys. These alloys, in the form of wire and strip, came into use in 1907, and were immediately applied to electric furnaces and electric heating appliances generally. Sold now under many fancy trade names, nickel-chromium alloys may be heated for long periods to 1,000°C, without oxidising or undergoing other deterioration. They possess the additional property, however, of offering a nearly constant resistance to electricity at all temperatures, and hence a furnace wound with such material may be coupled directly to mains without any danger of burning out; the time spent in gradually raising the temperature and the current expended in an external resistance in the old forms, being thus saved. It is quite safe to state that metal-wound furnaces would never have found a place in industry had not these alloys—or others possessing similar properties—been discovered. The immediate result was that small tube furnaces, in which the nickel-chromium alloy was wound on silica tubes, were marketed and secured a ready sale. Later, muffle furnaces of various sizes and shapes were manufactured, and at the present time furnaces with tubes 5 feet long and 1 foot in diameter are in common use.

Some typical examples of modern nickel-chromium furnaces may now be described. Fig. 1 shows a tube furnace made by A.

Fig. 1.—Tube Furnace (A. Gallenkamp & Co.).

Gallenkamp & Co., which is convenient for the estimation of carbon in steel by combustion, the glass tube in which the combustion is carried out being passed through the silica tube of the furnace, and held in position by asbestos stoppers. This furnace, which may be worked up to

1,000°C, may be used for experimental work of all kinds. The lagging consists of porous bricks of magnesia or kieselguhr, and the construction is such that a spare wound tube may be easily inserted by the user in case of a burn-out, thus avoiding the delay that would be caused by returning to the maker for repairs. Furnaces of this pattern, containing two or four tubes in the same casing, which may be used singly or together, are also provided. The power required to maintain a temperature of 1,000°C is 0.5 kilowatt for the single-tube furnace, and 1.2 for one in which four tubes are worked simultaneously, the length of tubes being 1 foot and diameter 1½ inches. Fig. 2 represents a muffle furnace by the same makers, which may be used for many laboratory purposes, and for the workshop treatment of tools of carbon steel. Fig. 3 shows a large tube furnace of a special type, intended for the hardening of steel tools, the heating being conducted in an atmosphere of coal gas, and the quenching bath being immediately below. A bright piece of steel, when heated in this furnace and quenched remains bright, and any damage due to surface oxidation is thus avoided. In all these furnaces accurate temperature control may be secured by means of an external rheostat.

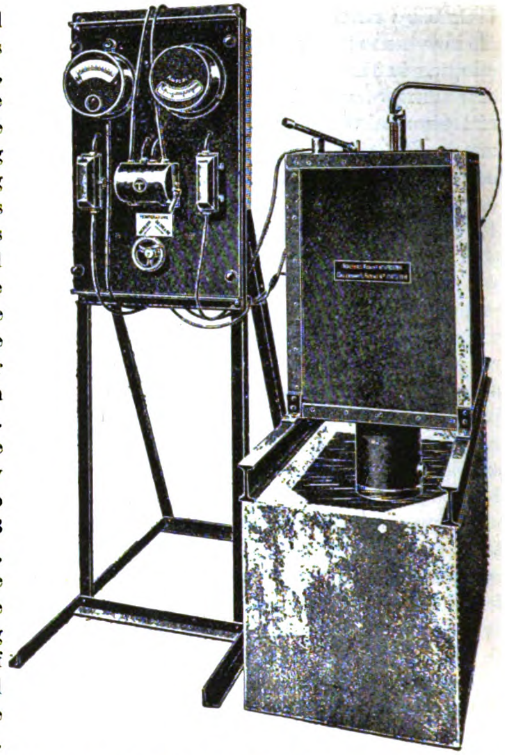

FIG. 3.—Steel-hardening furnace, with coal-gas atmosphere. (A. Gallenkamp & Co.).

The Leeds Electrical Construction Company have specialised on furnaces designed for industrial uses, such as the hardening and tempering of steel, the annealing of wire, and heating rivets. Fig. 4 illustrates a double-muffle furnace made by this firm, which is specially useful for the heat treatment of steel tools. Each muffle is separately wound, so that a different temperature may be used in each. The casing is strongly constructed, and mounted

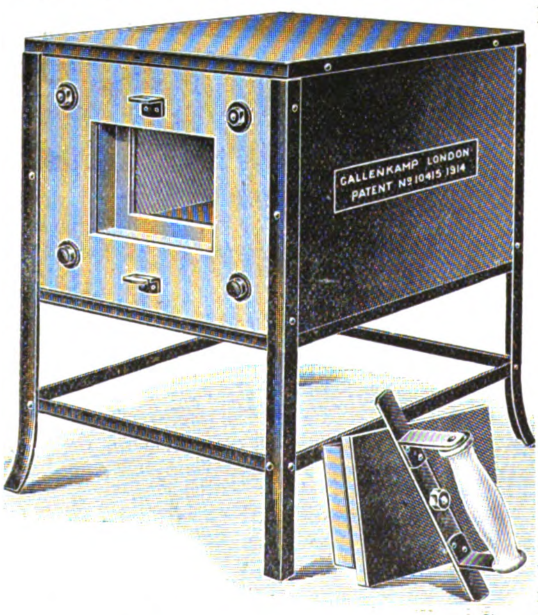

FIG. 2.—Muffle Furnace (A. Gallenkamp & Co.).

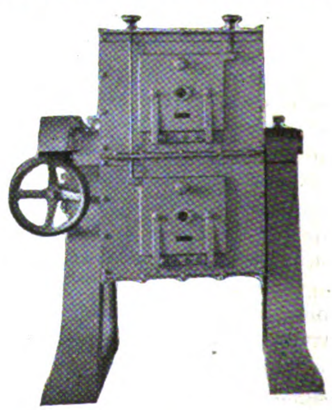

FIG. 4.—Double Muffle Furnace. (Leeds Electrical Construction Co.).

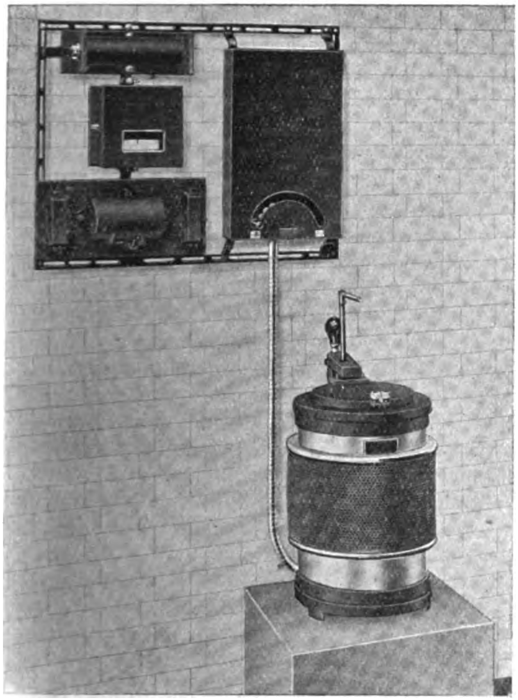

Fig. 5.—Vertical Steel-hardening Furnace. (Wild-Barfield).

so as to be capable of being tilted to discharge the contents. The dimensions of each muffle are 13ins. by 7ins. by 4ins., and each requires approximately 5 kilowatts. In the rivet heater made by this firm the rivets are fed into a circular furnace-tube with the shank end foremost. The whole furnace rotates about its longitudinal axis, and this rotation carries the rivets forward gradually, so that when the exit is reached the rivet is sufficiently hot for use. These furnaces are stated to heat 150 rivets, 2ins. long and ¾inch diameter, for a consumption of 5 kilowatt-hours. The same firm also supply furnaces for melting aluminium and other non-ferrous metals and alloys, in which the tube of the furnace acts as the crucible. Furnaces capable of melting up to 300 pounds of brass are manufactured.

The Wild-Barfield furnaces, manufactured by Automatic and Electric Furnaces, Ltd., are designed for use with the magnetic detector to be described later, and are extensively employed for the hardening of carbon steel. A special refractory is used, as silica, being a conductor at high temperatures, would interfere with the action of the detector. The refractory chosen does not conduct electricity appreciably at 1,000°C, and is wound with nickel-chromium alloy. Two chief forms are made, the vertical (Fig. 5) and the flat (Fig. 6). The sizes of the vertical form range from 2 to 12 inches in diameter, and from 13 to 37 inches in length, the smallest size consuming 0.9 kilowatt and the largest 12.6. The quantity of steel which may be hardened in one hour ranges from 5 to 100 pounds. A similar variety of sizes is also provided in the flat form. A useful device for preventing overheating is attached to each type of furnace, and consists of a loop of metallic silver inserted in the furnace, through which the current passes. Should the temperature of the furnace rise above the melting point of silver, 961°C, the loop will melt, and the current then passes through a red lamp shunted across the silver loop, which lights up and thus gives warning of excessive temperature, and by its resistance automatically reduces the current to a low value. The destruction of the winding by a negligent operator is thus avoided.

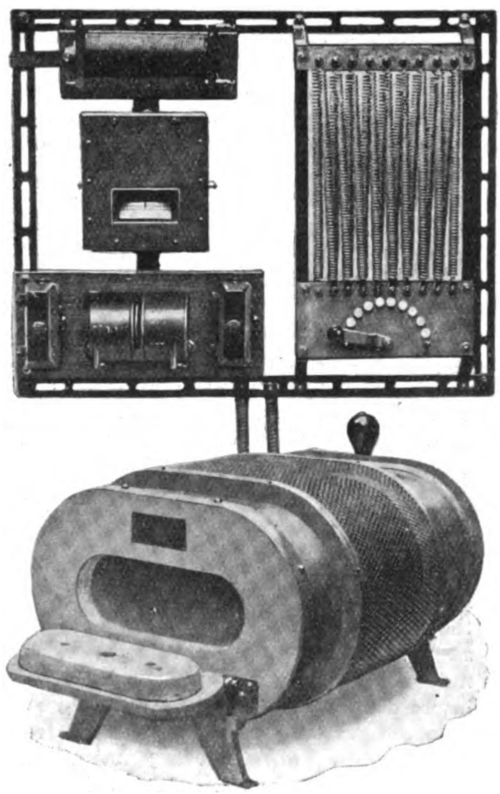

Fig. 6.—Flat Steel-hardening Furnace. (Wild-Barfield).

The furnaces described are examples of commercial types which have been made possible by the introduction of nickel-chromium alloys, and although the safe, continuous working temperature does not exceed 1,000°C, the number of uses to which they may be applied with advantage is so great that the manufacture of these furnaces has become a considerable industry in itself. In the laboratory they are used for experimental work on the heat treatment of metals, for incinerations and chemical combustions, standardising pyrometers, and as a substitute for gas-heating for many other purposes. In the workshop they are found of great service in hardening and tempering carbon-steel articles such as dies, punches, milling cutters, gear wheels, taps, gauges, and small objects such as sewing needles. In some of the large American factories, batteries of these furnaces are used for the hardening of gear wheels and other parts of machinery, the objects being heated to about 10° above the recalescence point, as indicated on a recording pyrometer, and then allowed to quench in a bath placed immediately beneath the furnace. This procedure ensures uniform results and is cleanly and cheaper to operate than gas heating; and it is to be hoped that British manufacturers engaged in mass production of articles will realise its economy and advantages. The nickel-chromium furnace is worthy of a much wider application in this country than it has yet received.

In all furnaces in which the heating element is wound round the refractory chamber, the heat must pass through the walls, and in consequence the heating of the interior is delayed owing to refractories, as a rule, being poor conductors of heat. In order to overcome this drawback furnaces have been designed in which the winding is fixed on the inside of the chamber, so that the heat is radiated directly on the objects. This arrangement is efficient, but can only be applied in cases in which the winding is not liable to damage from impacts with the articles undergoing treatment; in special cases, however, internal heating may be used to advantage. A point of interest in connexion with metal-wound furnaces generally is the relation between the temperatures of an external winding and the interior walls. On starting from the cold, the difference between these temperatures is considerable, but when a steady condition has been reached in the region of 900°C, experiments by Barfield show that this difference is only about 10°C. This indicates that the interior of a furnace may be raised to a temperature approaching the safety-point of the winding without risk of a burn-out.

Up to the present no generally satisfactory metal-wound furnace has been designed for continuous use above 1,000°C, or, at the outside limit, 1,100°C. The need for a furnace for the treatment of high-speed steel, involving temperatures between 1,300° and 1,400°C is generally recognised, but no metal or alloy has yet been found entirely suitable. Higher temperatures still are required for the annealing of the tungsten wire used for electric lamps, and a non-oxidising alloy, capable of withstanding 1,800°C and reasonably cheap would greatly extend the applications of metal-wound furnaces. The cost of platinum and kindred metals such as iridium, is too great to permit of their use for this purpose; and the metals of highest melting points, such as molybdenum (2,550°C) and tungsten (3,200°C), although fairly cheap, oxidise rapidly in air. No furnaces of this type are in use for the treatment of high-speed steel on the commercial scale, but the annealing of tungsten wire is carried out in furnaces wound with molybdenum or tungsten, arrangements being made to maintain an atmosphere of hydrogen throughout the furnace—a troublesome procedure which must always act as a deterrent to their general adoption. Molybdenum is preferable to tungsten for this purpose, being softer and more easy to work. Owing to the high temperature coefficient of these metals, care must be exercised when starting from the cold, so that an unduly large current is not passed through the windings. The opinions of users of these furnaces vary, some stating that they are fairly satisfactory, and others that they prove very costly in upkeep, owing to frequent failure of the winding.

If designed so that the heating element is always surrounded by hydrogen, and if kept under careful supervision when in use, there is no reason why molybdenum windings should not be very durable. All users agree that an alloy possessing the properties of nickel-chromium, but which could be used to 1,700° or 1,800°C, would be of the greatest value. Such an alloy will no doubt be forthcoming as the

result of metallurgical research. Incidentally, it may be pointed out that a small furnace capable of melting a few ounces of copper or gold, and which may be continuously heated to 1,150° or 1,200°C, would be of great use to goldsmiths and jewellers, whose work entails a higher temperature than may be safely attained by the use of nickel-chromium alloys.

Proposals have been made to use pyro-conducting refractories of the type employed in the Nernst filament lamp, and to heat up the furnace chamber to the conducting point by an auxiliary nichrom heater, which would be withdrawn when the conducting power of the refractory reached a sufficient value. The suggestion is interesting, but there are many difficulties in the way of its practical realisation.

Carbon Resistance Furnaces.

The need for a furnace giving temperatures up to 2,000°C, has led many workers to design appliances in which the resistance material is carbon, either in the form of graphite or the ordinary amorphous variety. Carbon will withstand a higher temperature than any other known substance, and is relatively cheap. It commences to oxidise in air at 600°C, and at higher temperatures the oxidation is rapid ; and hence provision must be made to prevent oxidation or to renew the material which has burnt away. Three chief types will be considered : (1) tube furnaces, in which the current is passed directly through the furnace tube, which is made of graphite or arc-lamp carbon ; (2) granular carbon furnaces, in which the refractory wall is surrounded by granules of carbon, through which the current is passed ; and (3) furnaces in which the refractory chamber is heated by carbon rods or strips through which the current circulates. Furnaces constructed on one or other of these patterns, but differing in detail are so numerous that separate descriptions cannot be given within the limits of the present paper, and typical examples only will be described.

The carbon-tube furnace is useful for special operations which demand a temperature of 2,000° to 2,500°C, such as the standardising of optical pyrometers. The tube is connected to the source of supply by means of water-cooled holders, and is lagged with lamp-black or porous carbon, as ordinary insulators will not withstand the temperatures reached. To prevent oxidation a continuous supply of nitrogen or hydrogen must be fed into the tube. A special source of current is needed owing to the low resistance of the tube, through which the current may be 100 amperes at a pressure of 10 volts. This involves the use of a special transformer when the furnace is operated from ordinary A.C. mains. It will be obvious that a device such as this is unsuited to general operations, but for particular purposes it has proved very useful. An example of this type of furnace is described by Harker in the Transactions of the Faraday Society, Vol. XII, 1917. With a tube ¾in. diameter a temperature of 2,000°C was attained in three minutes with an energy supply of 1 kilowatt ; and with an increased supply 2,500°C was easily reached.

A modified form of tube furnace is described by Rosenhain and Coad-Pryor, in the Transactions of the Faraday Society, Vol. XIV., Part 3, 1919. The tube in this case is built up of a number of separate graphite or carbon rings, machined so as to fit into each other. The contact resistance between the rings is utilised for the production of heat, with the advantage that the furnace may be operated with higher voltage, and smaller current than in the case of a continuous tube. A furnace constructed on these lines, having an internal diameter of 2¾in., attained a temperature of 1,500°C in 30 minutes, with a consumption of 8 K.V.A., and 1,700°C with 10 K.V.A., in which case the current was 400 amperes and the voltage 25. A plain carbon tube of the same dimensions would require 1,500 amperes at 6¾ volts, with the drawbacks attendant on the use of very high current strengths. The furnace withstood 100 heats at temperatures between 1,500° and 2,400°C, when a few of the top rings had to be renewed. This furnace was a distinct advance on its predecessors, but further simplification is needed before tube furnaces can be used in workshop routine.

Numerous forms of granular carbon furnaces have been devised, the current being passed through a layer of carbon particles (of a size retained on a 20-mesh sieve) which surround the refractory chamber. Fig. 7 shows a furnace of this type, intended for the testing of refractory materials. The current is led in by two iron electrodes, and where these are embedded the area of the carbon is large and the temperature lower than in the central region, where the carbon area is smallest

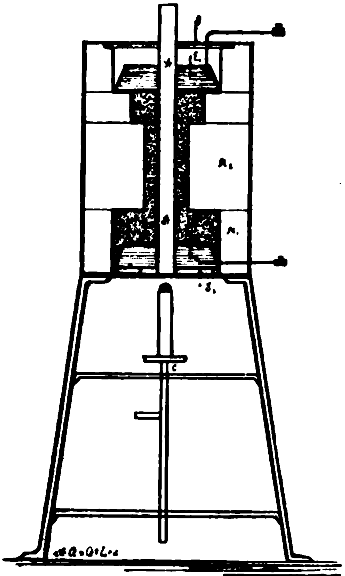

FIG. 7.—Granular Carbon Furnace.

and the temperature highest. The furnace tube passes down the centre. The material under test is placed on a refractory rod and raised so that the sample is opposite the centre of the tube, when its behaviour may be observed by looking down the top of the tube. For a heated length of 8 inches, and a diameter of 2½ inches, 10 kilowatts are required for a temperature of 1,700°C, the current being 125 amps. and the voltage 80. This furnace may be used on 100 volt mains—although wastefully—by using an external resistance, and on mains specially provided for arc-welding (70 or 80 volts) could be run with the maximum economy. One of the chief defects of granular resistance furnaces is the tendency to irregular heating, owing to lack of uniformity in packing, causing certain places to become hotter than others. To overcome this, furnaces have been made with a number of electrodes entering round the sides, and connected to switches, which enable the current to pass between any given pair, so that the temperature may be controlled in sections. Another drawback is the absence of a good refractory material which will withstand 2,000°C. Silfrax, a special form of carborundum, is one of the best for general purposes, and is said to hold up at 2,000°C, but alundum and fireclays droop before this temperature is reached. Zirconia and mixtures of magnesia and zirconia have been favourably reported on in the United States, but are only procurable with difficulty in this country. The development of the resistance furnace depends largely on the production of suitable refractories, and it is to be hoped that such will be available in the future. The granular furnace possesses the advantage of cheapness, and the current strength is such that a transformer is not needed to reduce the voltage from suitable mains, so that a direct-current supply may be used. The cost of renewal of the granular carbon is very small. The use of carbon strip in the form of a spiral cut from a graphite tube, enables a higher voltage, and less current to be used than in the case of a tube. Such a spiral was used by Arsem in 1905, in a furnace in which a vacuum was maintained to prevent oxidation. Others have constructed furnaces in which carbon spirals form the heating element, but the devices needed to prevent oxidaton form an undesirable feature, and none have come into general use. A later form of furnace, due to Hancock, consists of a number of carbon rods in series, running along the outside of the refractory chamber, and forming a kind of cage round it. The ends of the separate rods are connected by graphite strips, and both are preserved from oxidation by covering with a carborundum composition, highly compressing, and then baking at a high temperature. Carbon treated in this manner is highly resistant to oxidation, and by using a number of rods in series sufficient resistance can be built up to enable the furnace to be attached to mains. An external view of one of these furnaces is shown in Fig. 8. It is stated

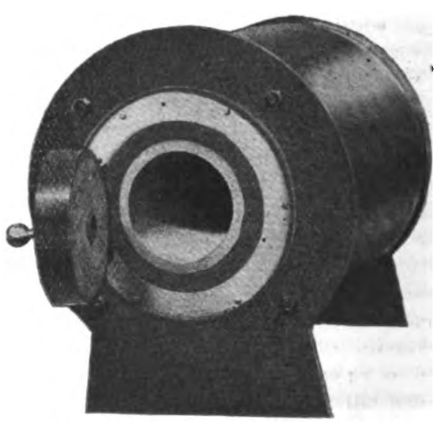

FIG. 8.—Hancock's Carbon Rod Furnace.

that a furnace 4 inches in diameter, with 14 inches of heated length consumes 5

kilowatts at 1,000°C, and 8 at 1,500°C. With a satisfactory refractory, a temperature of 2,000°C may be attained. This furnace appears to be the best at present available for the workshop treatment of high-speed steels, the prevention of oxidation of the carbon being overcome without the use of special gases or vacuum pumps.

Appliances Used in Conjunction with Resistance Furnaces.

The complete equipment of an electric furnace includes a small switchboard, on which is mounted an ammeter and adjusting rheostats. Safety cut-outs, in one or other form, are generally added to prevent an undue rise in temperature from any cause. In the case of low-voltage furnaces, a suitable transformer is requisite to step down from the voltage at the mains to that suited to the furnace.

A very useful addition to a furnace used for hardening carbon steel, is some form of magnetic detector. Experience shows that the best temperature at which to remove an article for quenching is that at which demagnetisation is just complete. This occurs at a temperature somewhat higher than that of decalescence, and as the loss of magnetic properties is not abrupt, a good magnetic detector should be capable of indicating the final stage of demagnetisation. It should, moreover, for general utility, be adapted for either a direct or an alternating current circuit. Bastian's indicator takes the form of a compass needle, suitably mounted on the exterior of a furnace in the construction of which no iron is used. The winding round the tube or muffle forms a solenoid, and when a direct current is passed through it a magnetic field is set up which causes a slight deflection of the compass needle. On inserting a steel object in the furnace the magnetic flux is greatly increased, and the needle strongly deflected. On demagnetisation commencing the needle swings back, and at completion returns to its original position, when the steel is removed and quenched. The two drawbacks to this simple plan are the necessity of keeping continuous watch on the compass, and the compulsory use of direct current.

Wild-Barfield's indicator, for use with alternating current, consists of a moving-coil placed between the poles of an electro-magnet, and carrying a pointer moving over a scale. The furnace has two windings, one round the furnace tube and the other round the exterior of the lagging, forming a primary and secondary. In the circuit is also placed a compensator, consisting of a primary and secondary and an adjustable iron core. The moving coil is inserted in the circuit in such a manner that when the current is switched on, and the compensator adjusted, the coil shows no deflection. On placing a piece of steel in the furnace this balance is disturbed, and the pointer moves along the scale. The beginning of demagnetisation is indicated by the return movement of the pointer, and when the original position is reached the process is complete and the article ready for quenching. The details of the circuit, and the theory of the instrument would take up too much space to describe completely, but may be found in the instructions issued with the furnace. For use with direct current, the same makers have used a secondary winding connected with a mirror galvanometer. The current induced in this secondary due to the diminishing flux on demagnetisation is indicated by the movement of the spot of light, which, on completion, will be back at its zero position. In both instruments continued observation is necessary to ensure that the change-point has not been passed.

A magnetic detector which gives an audible signal when demagnetisation is complete has been designed by the Hon.

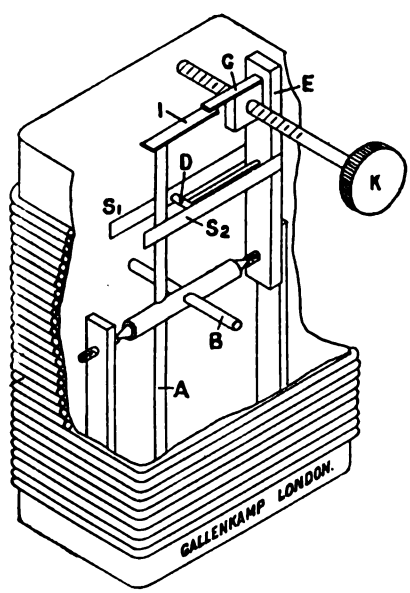

Fig. 9.—Action of Stopford-Darling Indicator.

C. W. Stopford and the author. Its action will be understood from Fig. 9. A piece of soft iron, A, is supported between pivots, and is caused to deflect by the coil C, which is placed in the circuit of the current supplied to the furnace. Two metal tongues, S_1 and S_2, are bridged by a metal piece, D, when the piece A is in the central position, and an electric bell or buzzer connected to S_1 and S_2 will then ring. The indicator is mounted on the end or side of the furnace, as shown in Fig. 10, and on switching on

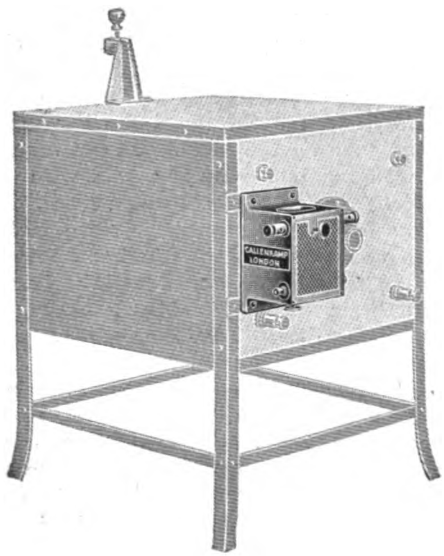

Fig. 10.—Stopford-Darling Indicator attached to Furnace.

the current A will deflect, partly owing to the coil C, and partly to the flux produced by the furnace. The circuit of the bell or buzzer will then be broken, and is just restored by turning the screw K, which moves the piece carrying S_1, S_2 and D. On placing a piece of steel in the furnace the deflection of A is greatly increased, and the sounding circuit is broken; but on complete demagnetisation A returns to its former position, and the bell or buzzer then sounds. This indicator gives very good results, does not need watching, and is suited to either direct ot alternating current.

The future developments of electrical resistance furnaces in workshop practice will largely depend upon cheap electricity, reliable refractories, and improved heating elements. The growth already attained is sufficient to indicate that an industry of considerable dimensions would result if these were forthcoming, and successful researches in connexion with the essential materials would be amply repaid. We may confidently look forward to a great extension of the uses of these furnaces, which, commencing as a convenience for research, furnish one more example of the truism that "the laboratory experiment of to-day is the workshop process of to-morrow."

DISCUSSION.

The Chairman (Sir Robert Hadfield), in opening the discussion, said the members had had that evening still one more proof of the wonderful nature of iron and its compounds. They had seen a steel which by its behaviour rang a bell and announced when it was hungry to be dipped and quenched. Perhaps he might refer to another steel which would not behave in that manner, viz., manganese steel, which, if heated or cooled, did not show any halt or change whatever in the cooling curve. Therefore, it would be of no use for the particular method of treatment described by the author. That showed how important it was to know the composition of the material with which one was dealing. No statement had been made that evening of the percentage of carbon in the specimens; perhaps Mr. Wild would state what it was. He noticed that the author had not referred to some very interesting experiments which had been carried out by the Morgan Crucible Company. About a month ago he had gone down to that Company's works, and he had seen them melt electrolytic iron, which required a temperature of about 1520° C., in a marvellously easy manner. It was done by that Company's latest method requiring special lining in the crucible. He supposed, too, that this was brought about by the electrical resistance method. It has been very wonderful to see electrolytic iron, which had the very high melting point of about 1500° C., run quite as easily and fluidly as cast iron. He had had the carbon determined in that specimen. Before melting, it was about .06%, and after melting about .08%, a very creditable performance from the fact that very little carbon had been absorbed. There were many minds at work on the problem of solving how to get high temperatures, not only for heat treatment purposes, but also for melting purposes. Only last week he had had some most interesting specimens sent him from Sweden by Dr. Westgren, who was doing such excellent work in the examination of iron and steel with X-ray methods. Dr. Westgien had sent him three very interesting specimens of iron, nickel and cobalt all melted with the cathode ray. It was rather a remarkable result to attain. He supposed something would be heard some day from those

people who believed in induction furnaces. In electric melting, his own firm used chiefly the Héroult system with the carbon electrode, and during the war they had by this method melted up no less than 100,000 tons of steel turnings, which otherwise would have been practically wasted. That showed how very useful the electric furnace could be for certain purposes. Cheap steel was not going to be produced by that method until cheap power was available. To-day, with coal at the present very high rate, cheap electric energy could not be expected to be obtained, but perhaps some day they would get an energy at .5d. or .4d., or even less. Then there would be no doubt that nearly all metallurgical operations must be carried on by electrical energy. That was one advantage of living near Niagara; very cheap electric energy could be obtained there, and that was the reason why such large numbers of factories had sprung up all round there. He had followed with much interest the classic experiment of the author's of the heating of the iron or steel wire, and had noticed the expansion and then the contraction; and also that very wonderful critical point upon which the heat treatment of iron and steel entirely depended. Before the war—not so much after the war, as the war seemed to have driven some sense of proportion into them—the newspapers had seemed to report generally that all great discoveries sprang from continental sources. The interesting experiment which the members had seen that evening with iron wire had been discovered by an Englishman, and had afterwards been elaborated still further also by an Englishman. He referred to Dr. Gore in the first instance, and to Sir William Barrett in the second instance. He thought a great debt of gratitude was due to those two men. One of them, his friend Sir William Barrett, was still with us, and engaged amongst other matters in psychical research. Apparently he had found the problem of iron and steel so great that he had gone into the easier problem of psychical research! There were no further comments which he wished to add. He had enjoyed the paper very much indeed, and he must congratulate the author most heartily on the lucid address he had given to the Society on matters of so much importance. How delighted everyone would have been to have such a lecture 25 years ago, but then, of course, it was not possible. The great advances of to-day had only been brought about and rendered possible by research, research and always research. If they could go on in the same way as they had been going on during the last 25 or 30 years, there need really be no fear for our country in the future as regards competition from abroad.

Mr. L. W. Wild remarked that the author had gone so very fully into the question of resistance furnaces that it left one very little more to say about it. Referring to refractories for laboratory furnaces of the size the author had exhibited that evening, silica made a very good refractory, but it became an utterly impossible thing for furnaces of really large sizes. The refractory makers of recent years had been going into the question of manufacturing refractories that did not crack, or that did not crack very much, and the progress had been very great indeed. As long as one was prepared to try anything which was offered, one could generally find something suitable for any purpose in time. He was glad to notice that the author had remarked upon the cheapness of electricity for heating, as compared with gas, for industrial purposes. There was not the least doubt about it, that the cost of current, where prices were reasonable, for an electrical furnace for hardening steel and the like, came out at less than the cost of gas for similar output—and he would emphasise "similar output." But a still greater saving was generally made on the cost of labour, partly by the use of unskilled labour or semi-skilled labour, and partly by getting a larger output per man. It was very difficult to get comparisons, but when they were obtained they were always on the right side for electricity. He agreed that for nickel-chrome windings 1,000° was the upper limit for industrial purposes, but in special cases, by using the very best quality wire, slow heating up, and careful nursing generally, one could make small laboratory furnaces quite satisfactorily up to 1,200°, as long as one was quite sure that one had the very best material. For the purpose of drawing tungsten filaments, the molybdenum wound furnace with hydrogen was, he believed, used with great success; but that was a special case, where the material was very expensive and where the final product was very expensive when bought by the ounce, and where one could afford to spend a good deal on the upkeep of the furnaces, and utilise special skill to look after them—which was not permissible in most industrial processes. He was very glad that the author was hopeful about obtaining an alloy for 1,800° C. It was what was most urgently wanted. The great difficulty would be to obtain a refractory to go with it. Unfortunately the usual process of making a refractory to stand high temperatures, was to take a powder—a refractory powder—and stick it together with a small quantity of ordinary fire-clay. The result was deformation. A refractory made up in that way, if used at a temperature of 1,800°, would probably attack the alloy. The refractory required for that work would be something of the nature of a pure alumina or pure zirconia, fritted or sintered together, at its own natural sintering temperature, without any additional bonding material whatever. That, he thought, would come when the wire came. It would be expensive, but it would come. The hot wire experiment shown that evening had been a very

interesting illustration of the recalescence of the wire on cooling, but he thought none of the audience had noticed what he had, namely, that the exact opposite had occurred on the heating. With heating at a certain point, the expansion had stopped, and there had been a slight contraction. The wire had gone up and then had come down again. It had been just at that point that the wire had really become non-magnetic. The Chairman had asked, what was the amount of carbon in the steel which had been put into the furnace. The fact was it did not matter. As long as there was over .4% of carbon, which was only just enough to harden, with that furnace the non-magnetic temperature was the right point for heating any steel with any amount of carbon that was ever employed in steel. It was also the right point for the heating of a good many of the alloy steels. A small quantity of tungsten or chromium or manganese or nickel, or any of the usual alloys, would harden perfectly, if carried up to the point at which they were non-magnetic. Where the non-magnetic point failed to be of use was where the amount of alloy became very large, as for example, in high-speed steel and stainless steel.

The Hon. C. W. Stopford said the author had pointed out that quite a lot of the information which one required in making such furnaces was not available in any books. There was one particular branch of information with which one was bound to be faced very soon, and that was the question of what materials might be brought in contact with the heating resistance wire. A short time ago, he had come across that difficulty rather badly. He had had occasion to fit up a small laboratory furnace, and he had used some lagging, largely consisting of mica, and the life of that furnace had been somewhere between 3 and 4 hours at a temperature of only about 900°. The nichrome wire had been a perfectly good brand; it had been quite a good alloy, but the effect of the mica lagging on it had been absolutely fatal. Some time ago, in looking up the matter of molybdenum and tungsten from the point of view of heating resistances, he had found that he could immediately get the information required in regard to those metals—or at any rate several of the things which one would be tempted to use—as to whether they were fatal or not; that was to say, one must not use hydro-carbon gases. But with regard to nichrome, he had never seen it mentioned anywhere. One would think that the makers of those alloys would give it in their catalogues, but he was not aware that they did, and personally, he should be grateful for some information of that sort.

Mr. J. R. Hancock said he should think that the only thing against the alloy which the author had mentioned, if it ever was produced, would be the cost. Probably it would be a most expensive alloy, whereas carbon rods could be obtained at the cost of a few shillings, and could be put in or drawn out of the furnace in about a matter of fifteen minutes. One of such furnaces had worked highly satisfactorily for a long period up to 1,700° C. actual test.

Mr. S. Jones said he had not had much experience with the refractories mentioned, but from the experience of other people at Teddington and the Royal Mint, he thought the ordinary refractories would be in evidence for a few years yet until something highly refractory came to hand. He had seen an experiment carried out at the Royal Mint last week in which an attempt was made to melt pieces of nickel in a crucible. A temperature of 900° C. had been reached, and then the crucible collapsed. He believed the cause of the collapse was a mystery.

The Chairman enquired whether it was a clay crucible or a plumbago crucible.

Mr. S. Jones replied that the crucible was made of magnesium oxide. It would stand a temperature of somewhere round 1,600° C., but it fell to pieces at between 700° and 800° C. owing to the nickel being melted in it. The material that was used for insulating the resistors, and which had proved wonderfully satisfactory, was alundum cement, which was imported from America. If anyone would like to try any of the material he would be only too pleased to send a sample.

Mr. Walter Hancock entirely agreed with Mr. Wild that in the case of a number of refractories, such as the carborundum series, the principle of using bonding clay was fatal, because ultimately it was only a question of the weakest link which broke the chain. Of course, there were methods of agglomerating those carborundum refractories and making them self-bonding. With regard to alundum, he thought perhaps on the whole it offered the best qualities for furnaces of the description under discussion; but silica was, of course, limited to relatively a low temperature compared with what they were really out to get, and it tended seriously to disintegrate. One of the difficulties with the furnaces, especially of the modern type, was that after a time small pieces of silica were liable to flake off and fall into the materials under treatment in the furnaces themselves. With regard to clay refractories, there was some feeling at the present time that they were distinctly unsatisfactory for the purpose. He did not quite know how a clay refractory compared, for example, with silica from the electrical point of view, *i.e.*, whether it was satisfactory as regards heat conductivity, but he did think that, if more careful attention was given to

the production of those refractory articles, a considerable advance could be made with the clays which were at their disposal. For instance, little attention was given to the actual grading of the materials employed in the construction of the articles. The clay itself undoubtedly should be ground as fine as was practicable, but the "grog" was very frequently added in quite a haphazard manner Much more attention ought to be paid not only to the proportion of grog that was added, but also to the various grade sizes which were employed for these articles. Then, too, the moulding of those articles—such as tubes and o on—had been done generally, up to recent times anyhow, by ordinary plastic moulding, whereas the possibilities which were held out by the casting process seemed to him to offer a very great advance on what could be done in the ordinary hand moulding. It was a matter of common experience that a muffle would either crack along the bottom or at the corners. That was largely due to faulty design. A few years ago a good deal had been heard of the possibilities of zirconia as a refractory material, but, unfortunately, there had not been as much information about it lately as could have been hoped for. On account of its peculiar chemical inertness and its actual refractory properties there was no question that zirconia offered very great possibilities, especially in work of the kind under discussion.

Mr. N. Cameron said he had noted the author's remarks on the Herœus furnace. He himself had been using one of those furnaces for nearly seven years, and he could speak very highly of it. Prior to the war he had used Herœus tubes, which ultimately got broken, and he now, unfortunately, found the greatest difficulty in replacing them with other Herœus tubes; in fact, he had been unable to replace them, although he had written to the Company, who had promised to look into the matter. Those Herœus tubes had been in use for nine or ten years.

The Chairman enquired at what temperature?

Mr. N. Cameron replied from 950° to 1,000°. Another point which he had found in using those furnaces was that he could on occasions go up to over 1,000° using nichrome wire on the Herœus tubes—the wire just being put straight on the tubes; but that when he used a silica tube with the nichrome wire, that was impossible. The silica started to soften, and there was a combination of the nichrome wire with the silica, and the furnace did not last very long. His Company had another furnace, about 35ft. long. It had about 450 to 500 ft. of nichrome wire in it. It was not run at high temperatures the maximum temperature being about 450°. That had also given satisfaction for nearly seven years with practically no replacements at all. It was for the annealing of glass. The furnace, however, in which he was particularly interested was the furnace for the treating of molybdenum, tungsten and nickel. All those furnace operations were done by his Company under a vacuum. They used a nichrome furnace, of course, and closed silica tubes. The silica tubes were about 5ft. long, and they were closed at one end. The metal was put in that: then they had another furnace about 3ft. 6in. by 4ft. long, and the tubes were placed straight into the furnace and left there until the required temperature was reached. They were then plunged into cold water. There was no need to worry about cooling down temperatures; they cooled their stuff down very quickly. That was the method his Company adopted. They treated molybdenum and tungsten spirals and also nickel wires in the same way. Very little had been said about nichrome strip *versus* the round nichrome wire. He had found from actual experience that the round wire was very much better than the strip. It was more durable, and the use of two wires in parallel, if possible, was more satisfactory than using one. He had asked from an English manufacturer of such a furnace a quotation, and had received in reply what he considered to be an exorbitant price, namely, £19. He could build the furnace in his own works for about £5 or £6, and until outside manufacturers were prepared to come down in price, he was afraid they would not get any business from his Company. Most of the paper dealt with the treatment of steel. As his experience had been with the treatment of molybdenum, tungsten and nickel he was afraid he could not say very much about the treatment of steel. He would, therefore, conclude by thanking the author for his valuable paper.

On the motion of the Chairman, a hearty vote of thanks was accorded to the author for his paper.

Mr. Darling, in reply, said one thing he would like to make clear was that he had not the wonderful new alloy up his sleeve, and that he was only speaking as an optimist, without any special knowledge of it. He might mention a little experience which he had in connexion with it. He had tried to get an alloy made to a definite composition. It was an alloy of aluminium and nickel in atomic proportions. That alloy had a very remarkable property, namely, of having a higher melting point than either the aluminium or the nickel. Generally, when metals were mixed, the melting point was lower than either of the ingredients; but in this case it was very much higher. As a matter of fact, the melting point of this alloy was about 1,600°, whereas pure nickel was about 1450°. He had thought that if he could get that alloy he might obtain a little higher temperature than with nichrome, if its properties

were satisfactory. He had tried to get it made. Everybody he had asked was going to make it and send it on in a week. It had never come yet. He had tried all kinds of firms. There must be some very great difficulty in making it. It had been originally described by the late Professor Richards, of the United States, and its properties were known from certain points of view. Whether it would make a good alloy for furnaces or not, he could not say. At the same time, however, on account of the metallurgical research that was constantly going on, he still adhered to his prediction that the alloy would be forthcoming, but he asked the members not to write to him for samples just yet. Referring to the induction furnace to which the Chairman had alluded, one had been brought out by Dr. Northrup in the United States. Strictly speaking, it was not a resistance furnace, and he had had to bar it out so as not to take up too much time. It was a high frequency furnace with a copper coil through which water was running. It was fed with a very high frequency current, and the crucible put into the interior of the coil was a graphite crucible, which would get to a temperature of 2,000° within two or three minutes owing to the induction effects on the graphite. In that way platinum could be melted up in a very short time indeed. It took place so quickly that there was no need of any lagging. The time for radiation was not great enough to matter, but the difficulty was in the supply of the high frequency current. Dr. Northrup first of all had used condensers, but the progress made in producing high-power thermionic valves appeared to afford another line upon which he might work for getting the necessary high frequency power. That, however, was a little off the track of resistance furnaces, but it was very interesting in the sense that it enabled one to get very high temperatures indeed. He thanked all the speakers for the remarks they had made. He always learned as much as anybody else on an occasion like the presentby hearing men who were working with the furnaces give their experience, so that every time he spoke about them afterwards he could say something which he was unable to say on the previous occasion. He thanked the Chairman for having given of his valuable time in order to preside. Sir Robert Hadfield was one of the busiest men in London, but, like all busy men, he could always find time to do things.

GENERAL NOTE.

FISHERY DEVELOPMENT IN SOUTHERN INDIA.—The *Pioneer* (Allahabad) calls attention to an interesting bulletin written by Mr. James Hornell, Director of the Madras Department of Fisheries. The Government chank fisheries on the East Coast which provide the shells for the chank bangle industry made a profit of 1½ lakhs of rupees in the three years ending with 1919-20, but since then the return has materially diminished owing to unfavourable markets, labour shortage and bad weather. The exceptional difficulties thus experienced have, however, now been overcome. Nothing has been done with the pearl fishery off Tinnevelly coast for some years, but inspection work is carried on in order that when the pearl oysters re-appear they may be fished at the right time. The fresh-water fisheries have made a good return to the Government and reference is made to the successful stocking of the Nilgiri streams with rainbow trout from New Zealand. In regard to sea-fishing the Department has been handicapped by the conservatism of the fisher people and the difficulty of procuring satisfactory teachers. But complete success has been attained on the operative side of the canning industry, which deals in the main with sardines, mackerel and prawns. The Indian oil sardine at its best is, in Mr. Hornell's opinion, fully equal to the true French sardine. The oil and fish guano factories have also yielded satisfactory results. At the close of the 1919-20 fishery year the factories numbered 653, the output being valued at nearly Rs. 28 lakhs.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, MARCH 26 .. Victoria Institute, 1, Central Buildings, Westminster, S.W., 4.30 p.m. The Rev. J. J. B. Coles, "Relativity and Christian Philosophy."

Royal Geographical Society, Æolian Hall, 135, New Bond Street, W., 8.30 p.m. Mr. Cuthbert Christy, "The Waterways of the Sudd Region, Bahr El Ghazal."

Production Engineers, Institution of, Newark Branch. Mr. C. G. H. Richardson, "The Manufacture of Aeroplanes."

Farmers' Club, at Surveyors' Institution, 12, Great George Street, S.W., 3.30 p.m. Prof. A. G. Ruston, "Economic Conditions of Agriculture at Home and Abroad."

Architectural Association, 34, Bedford Square, W.C., 7 p.m. Mr. Maurice E. Webb, "As Others See Us."

TUESDAY, MARCH 27 .. Illuminating Engineering Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 8 p.m. Mr. P. J. Waldram, "Window Design and the Measurement and Predetermination of Daylight Illumination."

Royal Photographic Society, 35, Russell Square, W.C., 7 p.m. Sir Frank Baines, C.V.O., C.B.E., "The History and Repair of the Roof of Westminster Hall."

Royal Colonial Institute, Hotel Victoria, Northumberland Avenue, W.C., 4 p.m. The Rev. Henry Gordon, "Life in Labrador."

Royal Anthropological Institute, 50, Great Russell Street, W.C., 8.15 p.m. Prof. W. Barthold, "The Nomads of Central Asia."

University of London, at University College, Gower Street, W.C., 5.30 p.m. Dr. Alexander Brigge, "The Viking Crusaders and their Bearing on British History." (Lecture III.)

WEDNESDAY, MARCH 28 .. Industrial League and Council, Caxton Hall, Westminster, S.W., 7.30 p.m. E. J. Garmeson, "The Function of Capital."

Geological Society, Burlington House, Piccadilly, W., 5.30 p.m.

Royal Society of Literature, 2, Bloomsbury Square, W.C., 5 p.m.

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***All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.* (2)**

NOTICES.

NEXT WEEK.

FRIDAY, APRIL 6th, at 4 p.m. (Indian Section).—GEOFFREY ROTHE CLARKE, C.S.I., O.B.E., I.C.S., Director-General, Posts and Telegraphs, India, "Postal and Telegraph Work in India." LORD MONTAGU OF BEAULIEU, K.C.I.E., C.S.I., will preside.

Further particulars of the Society's meetings will be found at the end of this number.

SIXTEENTH ORDINARY MEETING

WEDNESDAY, MARCH 21st, 1923; PROFESSOR E. H. STARLING, C.M.G., F.R.S., in the Chair.

The following Candidates were proposed for election as Fellows of the Society:—

Campbell, C. A., Tampico, Mexico.
Crowder, Martin Henry, Bombay, India.
Crowder, William Benjamin, London.
Hanslux, M., Delhi, India.
Neill, Miss Alma J., A.M., Ph.D., Oklahoma, U.S.A.
Ohlson, Olof, West Newton, Massachusetts, U.S.A.
Simpson, John Henry, Calcutta, India, and London.

The following candidates were duly elected Fellows of the Society:—

Davis, Professor Nelson Fithian, Sc.D., Lewisburg, Pennsylvania, U.S.A.
Gow, Jonathan Bertie, London.
Kapur, Sant Singh, Lahore, India.
Martin, Professor Dean W., Georgetown, Kentucky, U.S.A.
Nowak, Carl A., Sc.B., St. Louis, Missouri, U.S.A.
Parelwala, B. R., Bombay, India.
Thomas, Lieut.-Colonel Charles William, Stourbridge.
Tiddy, Richard Cyril, Calcutta, India.

A paper on "Some Curious Phenomena of Vision and their Practical Importance," was read by Dr. F. W. Edridge-Green, C.B.E., F.R.C.S., Special Examiner and Adviser of the Board of Trade on Colour Vision and Eyesight.

The paper and discussion will be published in a subsequent number of the *Journal*.

REPRINT OF CANTOR LECTURES.

The Cantor Lectures on "Brown Coals and Lignites," by WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, have been re-printed from the *Journal*, and the pamphlet (price 2*s*.) can be obtained on application to the Secretary, Royal Society of Arts, John Street, Adelphi, W.C. 2.

A full list of the lectures which have been re-printed and are still on sale can also be obtained on application.

PROCEEDINGS OF THE SOCIETY.

ELEVENTH ORDINARY MEETING.

WEDNESDAY, 14TH FEBRUARY, 1923.

MR. H. J. C. JOHNSTON (President of the Institution of Clay Workers) in the Chair.

THE CHAIRMAN, in introducing the lecturer, said he was afraid that, as a manufacturer of refractories, he was not qualified to speak on the question of their durability, for the reason that people who bought refractories never told the manufacturers anything about their durability, but only informed them as to their lack of it. It was very encouraging to see the Royal Society of Arts taking an interest in the question of refractory materials. The Great War had taught this country many lessons, one of which had been the importance attached to the manufacture of refractories. Fortunately, the industry of refractory materials was one of those few industries which had been successfully and properly controlled during the war period. Too much stress could not be laid upon the great part which the refractories industries had played in the shortening of the war, because not only had the scientists connected with re-

fractories industries, along with the manufacturers, served to the best of their ability the needs of the nation, but they had also contributed to the needs of our allies at a time when iron and steel had been very vitally required; and, although to-day the sword might be sheathed, the nation had to look ahead and be prepared for the time when war might once again break out, and it was very necessary that we should not be behind any other country in the most vital industry of refractories. Every encouragement, therefore, ought to be given to research in connection with all classes of refractory materials. The research which had been carried out in this country had been in excellent hands. The British nation had scientists in connection with the refractories industries who could hold their own with the scientists of any other country. In Mr. Rees it had a gentleman who was in the foremost rank of scientists engaged on this work. In addition to his very important and arduous work in connection with refractories at Sheffield University, he had been of very great assistance in collaborating with the British Refractories Research Association; in fact, that Association could not possibly have carried on its work without the assistance which Mr. Rees had afforded it in connection with a very important item of research. There was no one in the country better able to speak on the subject of refractories, from the scientific standpoint, than was Mr. Rees.

He would like to urge the necessity of encouraging research in regard to the industry. Unfortunately, the British Refractories Research Association, like many other Associations, had been founded at a somewhat calamitous time, and it would be a national calamity if, at the end of their present five years' period, that Association found itself unable to continue its work. He would like, through the meeting and through the Royal Society of Arts, to urge that every assistance should be given to the British Refractories Research Association so that the great work which they had started might be successfully carried on.

Mr. Rees had a great many friends and admirers throughout the body of manufacturers and users of refractories materials, and he was quite sure that, as a result of the lecture that night and the publicity which it would receive, Mr. Rees would add considerably to the number of those friends and admirers.

The following paper was read:—

THE DURABILITY OF REFRACTORIES.

By W. J. REES, B.Sc.Tech., F.I.C., Lecturer on Refractories, University of Sheffield.

The essential importance of refractory materials in present day civilisation needs no emphasis at a meeting of this Society. Their utilisation is at the basis of all industrial operations, and the consumption of them provides an adequate index to the condition of industry in general in any civilised community. During the European War, the limiting factor in the production of munitions was the rate of production and application of refractory materials for the building and maintenance of furnaces for the metallurgical, glass and ceramic industries. Much less than a generation ago it could be justly said that the technical study of the use of refractories in this country was on a much lower plane than in Germany, but during the last ten years the leeway has been made up to the advantage of both manufacturer and user. In many of our Universities and technical schools, the study of refractory materials is receiving increasing attention; for example, in the University of Sheffield, refractories is a final subject in the examinations for degrees and diplomas in metallurgy, fuel technology and glass technology, and the necessary courses of instruction are designed to give adequate knowledge of the properties and uses of refractory materials. It is scarcely necessary to dwell on the great importance of research in refractories, not only to the refractories industry itself, but to the basic industries of the country. It is noteworthy that in this vital matter we are no longer lagging behind; much valuable work has already been accomplished and the British Refractories Research Association is now in healthy existence. The manufacturers of refractories are keenly alive to the importance of research and their attitude offers every encouragement to those whose duty it is to carry on the work. Our natural resources of raw materials for the manufacture of fireclay and silica bricks are of great extent, and these products are to-day at least equal to those of any other country. Improvements can and will be made, but there is still room for work in the efficient utilisation of the products of to-day. A contributor to the discussion of a paper recently read by the author (1) suggested that the best silica firebrick of to-day is no better than that of five and twenty years ago; even if this were so, there is no doubt at all that the average quality of silica firebricks is decidedly higher now than formerly, and the same may be said of all types of commercial refractories. Nevertheless, the need for the production of

refractories of still higher grade is an urgent one; indeed, metallurgical progress is necessitating the provision of refractories which will have a high resistance to the severe conditions set up by higher working temperatures or highly active slags.

No single type of refractory can be expected to give adequate service in a variety of situations in a furnace where the conditions to be withstood are distinctly different. A difficulty which is in process of rapid removal has lain in the lack of precise knowledge of conditions existing in the various parts of industrial furnaces; this led at times to the use of materials the failure of which was inevitable. The selection of refractories which will have a high durability factor and so assist in maintaining a continuous output, is an important factor in the cost of production of metals, glass, etc. In particular cases the success or failure of a metallurgical operation may be entirely dependent on the suitability and quality of the refractories used for the construction and lining of the furnace. The life of a furnace or furnace lining should, therefore, not be measured in days, weeks or months (or even in heats); the factor to ascertain, and the only sound basis on which to make comparisons, is the cost of refractories per ton (or other unit) of saleable product. Adequate refractories will facilitate rapid production, and although the first cost of such material may be higher and their life no longer, very definite economies in cost of production may be possible. In the manufacture of glass, inadequate or badly selected refractories (such as pots or tank-blocks) may so seriously affect the quality of the glass as materially to reduce the quantity of saleable product. In such cases, the factor due to deterioration of product through "failure" of refractories is of vital importance. So far as temperature goes, the requirements of the glass industry are not nearly so drastic as in the steel industry, but because of the effect on the quality and physical properties of the glass, greater chemical resistivity is necessary.

Progress in the improvement of refractories or in the development of new types of refractory, can but be slow and hesitating if the only available test of their efficiency is that of behaviour under service conditions. This must, of course, be the final and conclusive test, but the selection and use of refractory materials cannot be placed on a truly scientific basis until their desired properties, both physical and chemical, can be specified and tested in measurable quantities. Tests are necessary which will enable reliable deductions to be drawn as to the probable behaviour of a refractory under any particular set of conditions. The proper testing of refractory materials therefore necessitates a clear understanding of the conditions which the materials will be called on to meet. It is, perhaps, desirable to point out that the term "failure" applied to refractories may have a wide range of meaning. Under severe conditions, the expected life may be only a few weeks, whilst under other less severe conditions it may be years. "Failure" may, therefore, be loosely defined in terms of a life much shorter than the average or in terms of a much higher cost in refractories per unit of satisfactory product. An analysis of "failures" which have come under the author's notice enables the placing of them into four classes:—

(*a*) Unsatisfactory quality, including lack of uniformity of quality.

(*b*) Faulty selection owing to the absence of knowledge of the conditions to be met.

(*c*) Faulty treatment of the material in service, due either to accident, carelessness or ignorance.

(*d*) Failure to allow a margin so that abnormal conditions of short duration may be withstood. (Or, in other words, the absence of a "factor of safety.")

Failures of the first class are in a decided minority when compared with those in the second and third classes. Typical examples of the second class (*b*) are the use of silica bricks in situations which are exposed to abrupt alternations of temperatures with only a moderately high maximum; the use of materials of low refractoriness in high temperature furnaces; and the use of coarse open-textured bricks exposed to the abrasive action of hot dust-laden gases. Typical examples of the third-class (*c*) are too rapid heating of silica brick structures; failure to relieve stresses due to expansion by slackening tie-bolts; the juxtaposition of materials which chemically interact at higher temperatures. Examples of the fourth class (*d*) are found in abnormal regenerator temperatures due to a breakdown in the reversing mechanism of regenerative furnaces and the temporary overloading of a steam-raising plant. Failures of the first

two classes should be completely eliminated; those of the third class can be eliminated to a marked extent by the education of charge-hands, or, as is done in a glass-manufacturing plant with which the author was connected, by the payment of a bonus to furnace operators on the tonnage-life of such refractories as melting-pots.

The standard methods of testing proposed by the refractories section of the Ceramic Society are well known and widely used, but the provision of other tests which give measurable results and the amplification of some of the existing tests are desirable. It is also desirable that tests should be conducted under conditions which are as near to the conditions of actual use as is possible. The question of the size of the test-piece has been frequently discussed; in the author's opinion tests on whole bricks are much more valuable than those on small portions of the brick. Better still is a test on a section of built-up brickwork, but this is beyond the resources of most laboratories.

For furnace construction and maintenance purposes, the most important refractories are silica, fireclay, magnesite and dolomite. Chrome, bauxite, zirconia, carborundum, graphite and alundum are also used to some extent. The following tables show the variations in chemical composition and the principal physical properties of these refractories.

TABLE III.

Fusion Points:

Fire-brick	1600–1720°C
Silica-brick	1650–1700°C
Magnesite	1900–2100°C
Chrome	1800–2000°C
Bauxite	1600–1800°C
Zirconia	2000–2500°C
Alundum	2000–2100°C
Carborundum	Decomposes at 2200°C

TABLE IV.

Behaviour under a load of 50lbs. per sq. in.:

Firebrick	Deforms at 1300°-1450°C.
Silica-brick	Rigid to 1500°C, Deforms or shears at 1550°-1680°C.
Magnesite	Shears at 1350°-1550°C
Bauxite	Deforms at 1350°-1500°C.
Zirconia	Deforms at 1450°-1650°C
Carborundum	Rigid at 1650°C.

TABLE V.

Specific Heats:

	100°C.	1000°C
Fire-brick	0.199	0.265
Silica-brick	0.219	0.263
Magnesite	0.231	0.324
Alundum	0.198	—
Carborundum	0.186	—

TABLE I.

	Fire-brick.	Silica Brick.	Bauxite.	Magnesite.	Dolomite.	Chrome.	Zirconia.	Carborundum.
SiO_2	50 to 80	90 to 97	4 to 15	2 to 14	2 to 8	3 to 10	5 to 15	0.2 to 5%
Al_2O_3	15 ,, 45	0.5 ,, 6	55 ,, 85	0.5 ,, 3	1 ,, 3	5 ,, 25	1 ,, 3	0.5 ,, 5%
Fe_2O_3	0.5 ,, 5	0.5 ,, 2	2 ,, 15	1 ,, 8	1 ,, 4	15 ,, 30	1 ,, 8	0.2 ,, 2%
TiO_2	0.5 ,, 3	0.10 ,, 0.5	1 ,, 7	—	—	—	0 ,, 3	— %
CaO	0.2 ,, 1.5	0.5 ,, 2.0	0 ,, 2	2 ,, 10	50 ,, 55	1 ,, 3	0 ,, 2	0 to 0.5%
MgO	0.2 ,, 1.5	0.1 ,, 0.5	0 ,, 2	72 ,, 94	30 ,, 38	3 ,, 15	0 ,, 2	— %
K_2O / Na_2O	0.5 ,, 2.5	0.4 ,, 1.0	0.5 ,, 2.5	—	—	—	—	— %
Cr_2O_3	—	—	—	—	—	35 ,, 55	—	— %
ZrO_2	—	—	—	—	—	—	70 ,, 85	— %
SiC	—	—	—	—	—	—	—	85 ,, 95%

TABLE II.

Specific Gravities:

Fire-brick	2.6 to 2.75
Silica-brick	2.3 ,, 2.50
Magnesite	3.2 ,, 3.60
Chrome	3.8 ,, 4.00
Bauxite	3.1 ,, 3.30
Zirconia	4.8 ,, 5.00
Alundum	3.9 ,, 4.00
Carborundum	3.1 ,, 3.20

TABLE VI.

Thermal Conductivities at 1000°C.

	Calories per c.cm. per second, per deg. C.
Fire-brick	.0038
Silica-brick	.0044
Magnesite	.0079
Chrome	.0057
Carborundum	.0231

TABLE VII.

ELECTRICAL RESISTIVITIES.

	Fireclay	Silica.	Magnesite.	Chrome	Bauxite	Zirconia	Bonded Carborundum.	Recryst-Carborundum.	Alundum
	Meg.	Meg.	Meg.	Meg.	Meg.	Meg.	Ohms.	Ohms.	Meg.
Cold ...	<137	<125	<137	48	<134	<134	107,200	106	—
	Ohms.			Ohms.	Ohms.	Ohms.			
800°C ...	57,600	2.38	5.0	803	109,000	558,000	12,550	6.5	16
		Ohms.							
900°C. ...	20,600	765,000	1.2	375	32,500	224,000	8,200	5.2	5
			Ohms.						
1,000°C. ...	10,800	300,000	708,000	171	17,200	131,300	7,400	4.1	1.8
1,100°C. ...	6,590	126,000	560,000	78	9,200	53,800	6,160	3.1	—
1,200°C. ...	4,160	62,000	193,500	63	6,100	7,710	4,160	2.4	—
1,300°C. ...	2,460	30,900	67,400	77	5,600	2,100	2,420	2.0	—
1,400°C. ...	1,420	16,500	22,400	85	2,200	960	1,430	1.7	—
1,500°C. ...	890	8,420	2,500	41	1,100	410	745	1.6	—

The durability of the refractories used for the construction and maintenance of furnaces is dependent on the following factors :—

1. The softening temperatures.
2. The mechanical strength at normal and high temperatures.
3. The thermal or reversible expansion.
4. The permanent expansion or contraction.
5. The resistance to abrasion.
6. The resistance to slag attack.
7. The permeability to gases and vapours at high temperatures.
8. The resistance to abrupt changes of temperature at high and low temperatures.
9. The changes in properties after prolonged heating.

The relative importance of these factors will naturally vary with the type of furnace.

The *texture* (in which term is summed up the homogeneity, extent of vitrification, porosity and the size and shape of the grains) of a refractory material will have an important influence on its durability, and in particular on its resistance to abrasion and spalling. Resistance to slag attack will be a factor of chemical composition and texture.

The softening point without load may be usefully examined by placing a whole brick on a convex refractory surface and, with a slow rate of heating, observing the temperature at which deformation occurs. In several instances the softening temperature thus obtained has been 50-100°C lower than that obtained in the standard test for softening temperatures which is conducted on small fragments. The following particulars relate to one such case :—The brick was of fireclay with a coarse texture, practically all the fragments of grog being rounded. The chemical analysis was—

Silica	..	65.69 per cent
Titanium Oxide	..	0.51 ,, ,,
Alumina	..	28.86 ,, ,,
Ferric Oxide	..	2.64 ,, ,,
Lime	..	0.43 ,, ,,
Magnesia	..	0.51 ,, ,,
Potassium Oxide	..	0.87 ,, ,,
Sodium Oxide	..	0.62 ,, ,,
		100.13

The normal softening point by Standard Test was equivalent to that of Cone 29-30 (1660°C). The whole brick when heated deformed at 1600°C, the rounded grog fragments apparently sliding over each other as soon as the matrix of the brick became only slightly viscous (See Fig. 1). In a

FIG. 1.

brick of similar chemical composition, but of finer texture, with angular grog, there was a close approximation between the indications of the two tests. In the whole brick test, volume changes and the influence of

furnace atmosphere can also be observed.

The mechanical strength of cold bricks varies with the texture and extent of burning. The following figures were obtained on testing a batch of even-textured hand-made firebricks having a normal refractoriness equivalent to Cone 30 (1670°C). The bricks were re-burned at 1200°C, 1300°C and 1400°C.

	Crushing strength. per sq. in.
Brick as delivered ..	2000 lbs.
Brick re-burned at 1200°C	2000 lbs.
Brick re-burned at 1300°C	2200 lbs.
Brick re-burned at 1400°C	2600 lbs.

The superiority of well burned bricks is indicated by these figures.

The mechanical strength of fireclay bricks is much lower at high temperatures owing to the gradual formation of a viscous condition in the brick. Dr. J. W. Mellor has shown that the sensitivity of a fireclay to load increases with increasing alumina content of the clay. This factor, associated with the interaction of the fluxing constituents of the brick with the other constituents, or the gradual softening of the product of these interactions during the burning of the brick, is responsible for the lower resistance to crushing strains at high temperatures. With normal-textured silica bricks the loss of mechanical strength at high temperatures is much less than with fireclay bricks because of the greater viscosity of silica and saturated silicate melts. Very fine textured silica bricks show a greater loss in mechanical strength than the normal-textured bricks unless they have been so well burned that the greater part of the quartz has been inverted and re-crystallised. In a series of tests carried out by Mellor and Emery(2) on 20 fireclay bricks of varying texture and refractoriness, the normal refractoriness varied from cones 26 to 33 (1580°-1730°C), whilst under a load of 50 lbs. per sq. in., deformation was complete at from Cone 13-20 (1380° - 1530°C). Bleininger and Brown(3) conducted a similar series of tests on 23 American fireclay bricks with normal refractoriness varying between Cones 26 and 34 (1580°-1750°C). Under a load of 50 lbs. per sq. in. deformation commenced between 1160° and 1330°C. The following particulars refer to tests conducted on two hand-made firebricks :—

	A.	B.
Silica	63.36%	57.14%
Titanium Oxide ..	1.02%	1.41%
Alumina	29.95%	37.44%
Iron Oxide	2.44%	2.39%
Lime	0.81%	0.31%
Magnesia	0.62%	0.24%
Potassium Oxide ..	1.02%	0.84%
Sodium Oxide ..	0.64%	0.31%
	99.86	100.08
Porosity	27%	24%
Normal Refractoriness	Cone 29 (1650°C)	Cone 34 (1750°C)
Deformation commenced under load of 50lbs. per sq. in ..	Cone 10 (1300°C)	Cone 14 (1410°C)
Severe distortion at ..	Cone 14 (1410°C)	Cone 20 (1530°C)
Cold crushing strength in lbs. per sq. in. ..	2500	3500

Despite the higher alumina content of brick B., the more fusible matrix which would be present in brick A causes a greater reduction in refractoriness under load. A simple method of applying the load test is to support a brick on its two ends leaving a clear span of 7 or 8 inches, and load it in the centre with a heavy brick (such as a chrome brick) on end. Then heat to 1400°C (or upwards) and observe the deformation, if any, produced. This type of test is particularly useful in observing the strength of fireclay mixtures used in making glass-house pots or steel-melting crucibles.

The thermal or reversible expansion is an important factor in the use of silica bricks, because of the $\alpha - \beta$ inversions

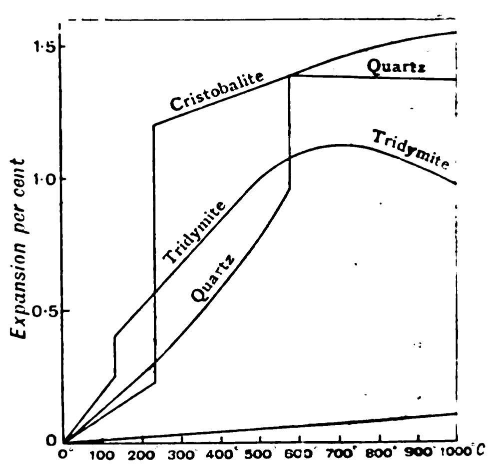


Fig. 2.

which, with quartz and cristobalite, are accompanied by marked volume changes (See Fig. 2). Messrs. Cobb, Hodsman and Houldsworth(4) have investigated this factor for numerous types of brick and their results indicate that in firebricks containing free quartz, the thermal properties of the quartz are only slightly masked by the presence of the fireclay. The rapid increase in the rate of expansion at 575°C due to the α-β change in the quartz is almost as marked in a semi-silica as in a normal silica brick (See Figs. 3 and 4). Just as

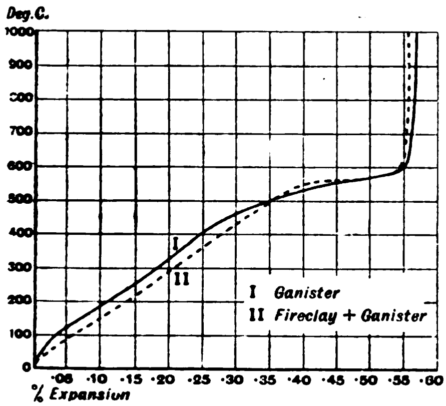


FIG. 3.

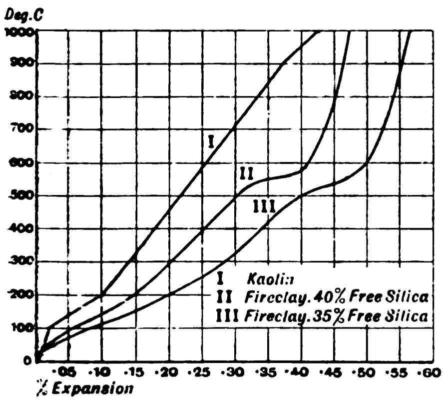


FIG. 4.

much care, therefore, is necessary in heating a structure (a coke oven for example) built of semi-silica bricks as one built of silica bricks.

The Standard After-Contraction or After-Expansion test is designed to indicate the permanent volume change which the brick is likely to undergo when in use at high temperature. Experimental work by Miss Jones(5) indicates the advantage of the use of small test-pieces cut from bricks. So long as the bricks are homogeneous both in texture and burning, the author is in agreement with these conclusions, but in some bricks tested in this way, contradictory results have been obtained from small test-pieces because of variations in texture and burning throughout the brick. Results which have accorded well with the behaviour of bricks in use have been obtained in the author's laboratory by slowly heating whole bricks to the test temperature (Cone 14. 1410°C), and maintaining that temperature for four hours. A useful test is to heat one-half of a brick for a few hours at the temperature at which it is to be used, and then to compare the two halves of the brick. J. W. Mellor(6) has examined the influence of furnace atmosphere on the high temperature volume changes of firebricks. In the author's own experience bricks high in iron-oxide and silica show a rapid contraction at 1100°C-1200°C due to the formation of fusible ferrous silicate, particularly in a reducing atmosphere. Above 1350°C such bricks expand again, bloating having occurred. When it is known that a particular brick is to be used under reducing conditions the test should be made under comparable conditions.

With silica bricks there appears to be a definite linear connection between the true specific gravity and after-expansion. Fig. 5 gives the results of about 30 tests of commercial silica bricks(7). The majority of the after-expansion results lie on a straight line; those which deviate from it having a very coarse texture. With American silica bricks, Harvey and Moore found a difference in the behaviour of bricks made from Medina and Baraboo quartzites, the heat treatment which resulted in a certain proportion of quartz conversion with Medina bricks, giving a smaller proportion of conversion with Baraboo bricks. With British bricks differences of texture appear (assuming approximately equal lime content) to have a greater effect on the rate of conversion than differences in the source of the raw material. It should be possible, however, for a manufacturer of silica bricks to prepare from experimental data a chart on which the after-expansion could be read off from a determination of the true specific gravity.

At present there is no quantitative method for determining the resistance of refractories to abrasion and to slag attack, the available methods being purely comparative. Mellor and Emery(8) devised a method for observing

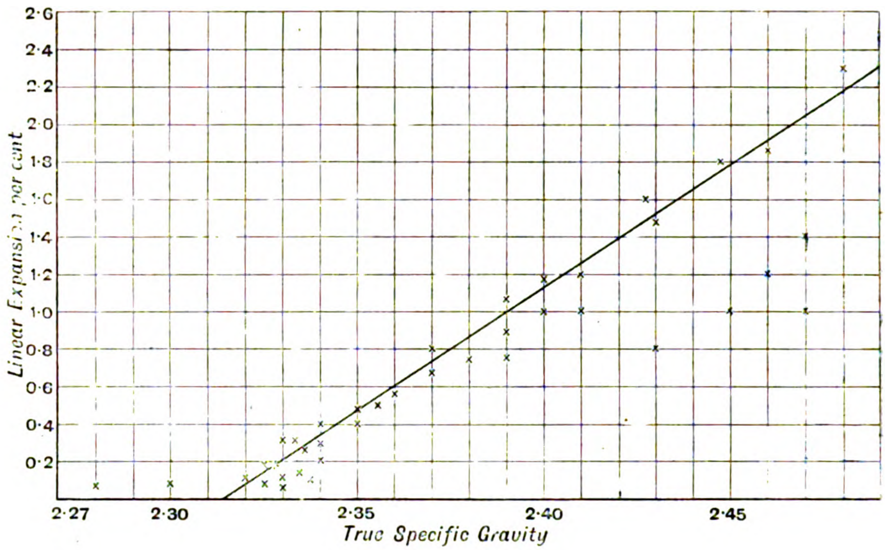


FIG. 5.

the abrading or corrosive action of hot dust-laden gases on bricks by feeding a stream of dust into the blast entering the burner of a furnace. Observations of this type are important in connection with refractories for use in furnace ports, regenerators and high temperature boiler arches and fire-boxes. The resistance of a refractory to the corrosion of a slag, dust or ash may be roughly determined by drilling a hole in the brick, filling it with the slag or ash and heating under pre-determined conditions. The brick is then cut or broken across the hole and the extent of corrosion or depth of penetration observed. (See Fig. 6.) A

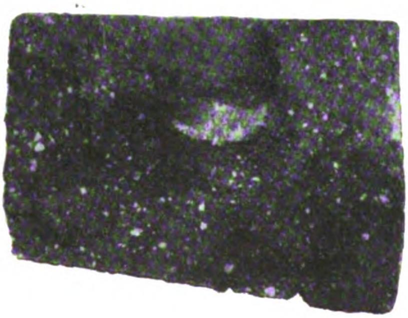


FIG. 6.

rather better method(9) is to cement to the face of the brick a clay ring and fill this with the slag or ash as the face or skin of the brick is not then removed (see Fig. 7). The lower porosity of the face of the brick may retard the speed of corrosion. The

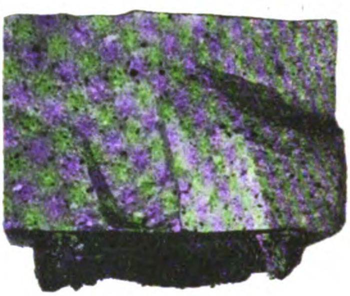
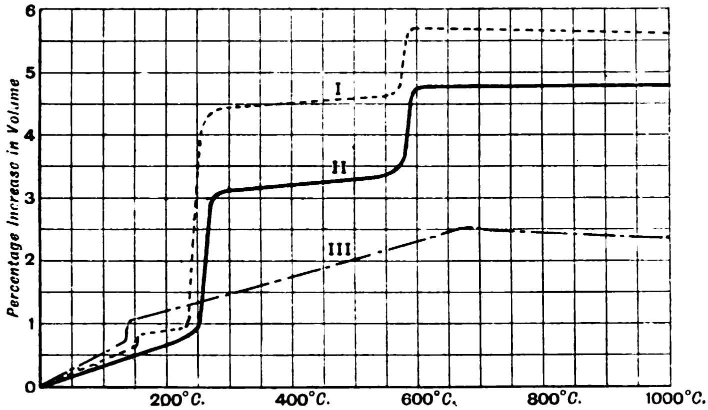


FIG. 7.

author has recently observed the corrosive action of two coal ashes of the following approximate analyses :—

	A	*B*
Silica	37.0	30.0
Iron Oxide	26.9	2.9
Alumina	25.2	34.4
Lime	1.9	12.9
Magnesia	1.8	4.4
Alkalies (as K_2O) ..	3.8	5.4
Fusion Point	1260°C	1150°C.

The observations were made by the ring method. Under reducing conditions the corrosive action of ash A on a siliceous firebrick at 1,400°C. was severe, but much less marked on an aluminous brick. Under oxidising conditions the siliceous firebrick was much more resistant to the corrosion, the difference between the resistance of the two types of brick being less marked. With ash B there was very little difference in the corrosive action under oxidising or reducing



Reversible Expansion of Silica Bricks
I 50% Quartz, 50% Cristobalite,
II 25% Quartz, 60% Cristobalite, 15% Tridymite
III 5% Quartz, 95% Tridymite

FIG. 7.

conditions. The attack on a siliceous brick was in both cases much more severe than on an aluminous brick. In other cases examined, a high resistance to the corrosion of coal ash at high temperatures has been given by a well-made siliceous firebrick (85% silica) of low porosity. The porosity of the brick is an important factor in the resistance to both abrasion and slag attack, but the determining factor may be the facility with which the brick face becomes covered with a protective glaze either by its own surface semi-fusion or by intersection of the brick with the dust or ash. With silica or highly siliceous bricks the high viscosity of such skin glazes may considerably retard corrosion. In fire boxes and boiler arches a brick which readily glazes in this way may quite well have greater durability than one which has a greater intrinsic refractoriness. The development of powdered fuel and oil firing lends particular importance at the present time to this particular property because the formation of this skin or glaze on the exposed face of the brick reduces the permeability of the brick to hot gases or vapours and prevents disruption of the brick from reactions (such as carbon monoxide cracking with deposition of carbon) which may take place in its interior.

The "spalling" tendency of refractory bricks is another factor with an important bearing on durability, particularly in furnaces which are only intermittently at high temperature. This tendency may be due to a rapid increase in the rate of expansion over a particular short temperature range—this is the case with silica bricks when the α-β change in cristobalite at 240° C. and in quartz at 575° C. is accompanied by an appreciable volume change (see Fig. 7)—to a high co-efficient of expansion accompanied possibly by a low thermal conductivity; or to continuing contraction of the hot end of the brick, this latter being a frequent cause of spalling in magnesite or highly aluminous bricks; or to repeated abrupt temperature changes. There is no really satisfactory quantitative method for the determination of spalling tendency. McDowell[10] determines the reduction in the modulus of rupture of the bricks after heating to 600° C for some hours and cooling with free access of cold air. Howe and Ferguson[11] have devised a method which the author has found to give results of comparative value. The bricks are heated to 1,300° C.-1,350° C., and after one hour they are removed from the furnace and immersed to a depth of four inches in a tank of flowing cold water or exposed to a cold air blast. The spalling tendency is estimated by the loss after repeated treatment in this way. Clays with a long vitrification range produce bricks which are more subject to spalling than those in which the porosity is approximately constant over a wide range of temperature. Porosity-temperature determinations should, therefore, indicate what clays are likely to produce bricks with the highest durability in situations where spalling troubles have been encountered, or should indicate what modifications are necessary in clay mixtures in order to

increase resistance to spalling.

The changes in both physical and chemical properties which may occur during the life of the refractory may have a profound influence on durability. Brief mention has already been made of the effect of expansion or contraction of the brick and of the effect of skin glazing or vitrification. In the open hearth furnace deep seated changes take place in the silica bricks, their structure and chemical composition being progressively altered between the hot face and the cold end. The beginning of these changes, or, in other words, the "seasoning" of the bricks, greatly affects the subsequent life of the bricks. The changes in chemical composition and structure are shown in Table VIII. and Fig. 8.

In silica bricks which are to be used for the building of coke-ovens a high degree of quartz conversion is essential as growth of the brick due to continuing conversion of quartz to the forms of lower specific gravity must be avoided. When the coals which are being coked are non-salty, satisfactory durability is obtained from either fireclay or semi-silica bricks, but there appears to be definite evidence from American practice that a silica brick oven-construction renders possible the use of higher coking temperatures and a larger output from an oven of given size without any sacrifice of by-products. Both from this point of view and because of the greater resistance they offer to salt-corrosion, and their higher thermal conductivity [or

TABLE VIII.

SILICA BRICK FROM ROOF OF ACID OPEN-HEARTH FURNACE.

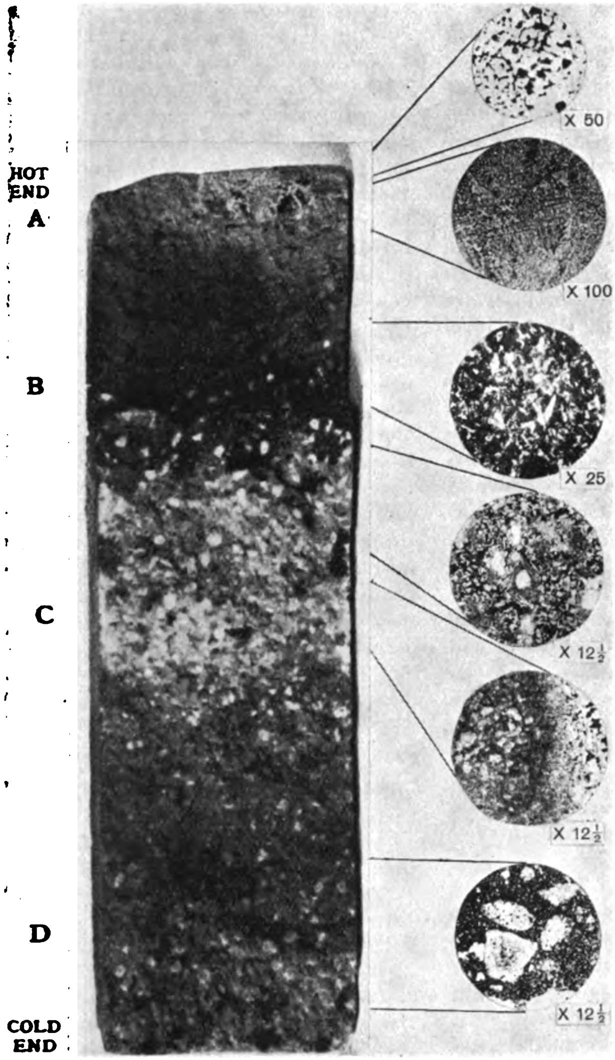
Zone.	SiO_2	Fe_2O_3	FeO	Al_2O_3	CaO	MgO	Mn_3O_4
A	80.5	11.6	6.4	0.9	0.2	—	0.4
B	75.4	18.5	3.8	1.2	0.4	—	0.3
C	89.4		3.1	2.8	3.9	0.15	0.1
D	95.2		1.1	1.4	1.8	0.10	—

SILICA BRICK FROM ROOF OF BASIC OPEN-HEARTH FURNACE.

Zone.	SiO_2	Fe_2O_3	FeO	Al_2O_3	CaO	MgO	Mn_3O_4
A	87.4	5.6	1.4	0.9	2.8	0.4	1.3
B	86.8	6.6	0.9	1.2	3.1	0.4	1.0
C	89.4	3.1		2.1	4.5	0.2	0.4
D	95.8	0.9		1.1	1.5	0.2	—

The author has been told more than once by furnace operators that a silica brick which "seasons" well will have a satisfactory durability. There has been much discussion as to the advantage or otherwise of high quartz conversion in promoting the durability of silica bricks in the open-hearth furnace. H. H. Thomas(12) has suggested that the actual density-concentration of silica is of more importance than the crystalline form in which it is present. There is much to be said in support of this view, but the author's experience is that both high quartz conversion and high silica concentration are desirable if maximum durability is to be obtained. In this latter case, durability may also be promoted indirectly by the greater structural stability of the roof as alterations in contour from high after-expansion may aversely affect the economies of the furnace.

diffusivity(13)] the author strongly advocates the use of silica bricks in coke-oven construction. From analytical data obtained from some washed slacks from South Yorkshire coke-ovens the author has calculated that approximately 50 lbs. of salt is carried into the oven with each charge of drained slack(14). The corrosion resulting from the presence of this salt is a comparatively low temperature phenomenon, as the salt begins to volatilise at 800° C, and there is also some carrying of salt by hydrolysis, as steam from the centre of the charge comes in contact with the hot coal. J. W. Cobb(15) has shown that interaction between alkalies, lime and silica will take place at temperatures much below that of fusion of the mixtures, and there is evidence that this type of reaction is important in coke-oven corrosion. In the coke oven the internal wall does not reach the temperature (1,200° C.) at which



Complete penetration of brick by iron oxide.

Skeletal crystals of cristobalite in glassy matrix.

Large proportion of the quartz converted to twinned tridymite.

Tridymite crystals with residual quartz fragments surrounded by cristobalite.

Fragments of unconverted quartz with cristobalite and tridymite in the matrix.

This portion of the brick is practically unchanged. The fragments of ganister have unaltered cores.

FIG. 8.

salt-glazing takes place rapidly, and the salt vapour instead of reacting with the surface of the bricks penetrates them and reaches a zone in the brickwork where the temperature is high enough for interaction between salt and fire clay to take place with some rapidity. The joint result of slow interaction in the cooler portion of the brick and the more rapid action in the hotter zone is the formation of a vesicular mass, increasingly open to the attack of the salt and likely to fall away or be dragged away by the moving coal or coke. Facing or glazing the exposed face of bricks in order to increase their resistance to corrosion, has not been successful owing to differential expansion, the prepared face falling away. There is now no difficulty in obtaining in this country silica bricks which will fully meet the stringent specification necessary for coke-oven use. Some which the author has tested recently are at least equal to the best American or Continental bricks. Where high coking temperatures are employed the greater mechanical strength of good silica bricks is a consideration of importance to the oven builder. Even the highest grade of fireclay brick will deform under load at a temperature well below its normal softening point, whilst a highly converted silica brick of low porosity will carry load almost up to its fusion point. At high coking temperatures, therefore, the durability of adequately made

silica bricks will exceed that of bricks made wholly, or in part, of fireclay.

Another example of internal low-temperature reactions adversely affecting durability is to be found in the corrosion of glass-furnace tank-blocks. Instances have been cited(16) where the corrosion of tank-blocks has been increased when the working temperature of the furnace has been reduced, without any alteration in the batch. In such cases corrosion is particularly severe below the metal level. At the metal level the temperature is high enough for interaction between glass and block to take place at the block face, but below the metal level where the temperature is lower, the molten glass is absorbed by the porous block and interaction between glass and clay will occur inside the block at a temperature below the melting point of the glass. The physical properties of that portion of the block will be materially altered and there will be a consequent spalling away of the face of the block and the rate of wear will be accentuated as the fresh surface of porous block is exposed to the glass. Some of the wear of tank-blocks both at and below the metal level is due to mechanical erosion by the moving glass. Wear of this type, as well as actual chemical corrosion, may be retarded by the use of well-burned fireclay blocks of low porosity.

The higher temperatures which are necessary for the satisfactory development of some of the modern metallurgical operations are causing attention to be directed to refractory materials with higher melting points than those normally employed. In some of these cases the higher initial cost of such special refractories as those made of carborundum, fused alumina, zirconium silicate and sillimanite may be more than offset by the greater durability obtained. The author has recently been examining the behaviour of zirconium silicate as a refractory. It appears to be free from the tendency to form the carbide in the presence of carbon monoxide at high temperature which has militated against the use of zirconium oxide. The success or failure of these special refractories depends entirely on their durability factor in pounds, shillings and pence.

The prolongation of the life of furnace linings by the application of cooling devices to the external surfaces has been demonstrated by the application of water-cooling to the blast furnace and the open hearth furnace(17). Besides water-cooling it is possible to use cold air, blown by fans or delivered from a compressor through nozzles; air saturated with moisture or steam-jets. By any of these means the temperature gradient through the furnace lining may be materially altered and the corrosion of the internal surface retarded. The cost of the installation and maintenance of such cooling devices must be set off against the reduced consumption in the furnace. A limit to the expenditure in cooling is thus soon reached.

In conclusion, the author would emphasise the desirability of collaboration between the maker and user of refractories. It is frequently in evidence nowadays, and when the maker of refractories has adequate knowledge of the physical and chemical properties of his raw materials and products, and the user has adequate knowledge of the conditions existing throughout his furnaces, then the way is clear for proper specification or selection.

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(5). Trans. Ceram. Soc. 1923.
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DISCUSSION.

THE CHAIRMAN (Mr. H. J. C. Johnston), in opening the discussion, said for the greater part of Mr. Rees' paper he had been wondering what he could say in the way of criticism of the paper, because, of course, remarks in the form of praise were rather a useless mode of discussion. He was sorry that Mr. Rees had not amplified further in his paper the idea of judging refractories by service. Mr. Rees had introduced that idea in the early part of the paper, and had stated that it was going to be his text, but he had departed a little from that text, and had discussed other ways of judging refractories. It was a text, however, which required impressing upon both manufacturers and users—particularly users—of refractories in this country. The idea of buying refractory

materials for their initial cost, or even on laboratory test, was one which ought to go by the board.

What had interested him most was the reference to coke ovens. He had followed the paper very carefully, and had noticed that in every other part of it Mr. Rees had supported, by data or by lantern slides or tables, the statements which he had made, but scientific gentlemen, when they had not the data with which to support their assertions, gave it as their "expressed opinion," and that was what Mr. Rees had done in connection with the use of silica bricks for coke ovens. He was bound to say that he did not think the data at present available (and many coke oven managers were of the same opinion) justified Mr. Rees' statements, particularly in view of Mr. Rees' own remarks as to silica bricks containing a high degree of quartz conversion. It was rather daring of him to have put slides on the screen which showed 95 per cent. of tridymite, or even 15 per cent. of tridymite. He did not know where Mr. Rees found silica bricks with that high percentage of tridymite. They had been heard about in scientific papers read before the Ceramic Society and other similar Bodies. The members of the Ceramic Society had had a very illuminating contribution some years ago by two scientists mentioned in the paper, namely, Cobb and Holdsworth, in which those gentlemen stated that they had examined commercial samples of every silica brick in the country, and that they had been unable to find any commercial silica brick containing any trace of tridymite. That statement was recorded in the transactions of the Ceramic Society, and therefore it was not much use Mr. Rees, or anyone else, saying that coke ovens could be successfully constructed with a class of bricks which did not exist.

MR. CHARLES R. DARLING, F.Inst.P., F.I.C., said one thing which had struck him in the paper had been the very great progress which had been made in the method of attacking the problems connected with refractories. He remembered some years ago attending the Conference on Refractories promoted by the Faraday Society during the war. Some of the methods then suggested as being desirable for solving refractory problems had evidently now become standard laboratory practice, and he could not but think that very great value would result from approaching the problem, not in the rule-of-thumb manner—not by merely putting a brick into a furnace and seeing what happened to it—but by going about it in a proper scientific way.

There was one point about which he would like to ask Mr. Rees a question, and that was in regard to the bricks which were covered over with a glaze and were thereby protected. That was in connection with bricks subjected to hot dust and ash, such, for example, as the arch of a furnace when powdered fuel was being used. He would like to know how one could tell whether a brick was going to be a good one or not. Supposing one wanted to buy a brick for the arch of a furnace in which powdered fuel was going to be used, what would one go by in selecting such a brick? That was a problem which he had been up against several times. He had been recommended bricks, and had bought them, but they had proved to be useless. If Mr. Rees could tell him any way of saying beforehand that a brick of a certain definite qualification would be best for the job, he would be grateful.

The part of the paper which interested him most in relation to the particular work in which he was engaged, was that part of which, unfortunately, not much had been heard that night, namely, the part which dealt with the higher refractories. The fire-brick which one used in a steel melting furnace, and so on, was what he called a low melting point material. It used to be called a high melting point material, but now, in dealing with metals like tungsten which had a melting point of 3200°, or molybdenum which had a melting point of 2500°, one got into a higher range of temperatures, and wanted refractories to match. A certain amount of progress had been made, but so far we had not been able to get those refractories at all satisfactory. Great results had been promised some time ago from Zirconia, but the drawback to that was that it very easily formed carbide. One trouble appeared to be with the bonding. His own experience of refractories had been somewhat disappointing. He had been hung up for a long time for a refractory which would obey the conditions which he required. He wanted a refractory which would stand a temperature of 1800°C. which would not be porous to metals under a head of molten metal of one foot, and which at the same time was not a very good conductor of electricity when hot. Those were, perhaps, very exacting conditions for a refractory, but if anyone knew of a refractory which would obey them, he would very much like to hear of it.

He had been deeply interested in the work which Mr. Rees had been doing on zirconium silicate as a refractory which appeared to be free from the tendency to form carbide. He did not carry in his mind the melting point of zirconium silicate, but he did know that he had tried some small experiments in bonding it and he had never been successful in getting a satisfactory bond. He thought that that might have helped him in solving the problem he was working on, but he had not been able to get a satisfactory bonding. He did not know if Mr. Rees had made experiments on the bonding of zirconium silicate so as to shape it, not in mere bricks, but into shaped refractories, such as tubes or muffles. He should much like to know what bond could be used.

The only other matter to which he would refer was the difficulty that one had in this country in getting a refractory made up to a specified shape. One was generally met with the statement that if a gross were ordered, it would be done, but as only one or two were required for research purposes the manufacturers would not look at it. Whenever he had been compelled to get a refractory he regretted to say that he had been driven out of this country and had had to go abroad to obtain it. He did wish that refractory makers in this country would give a little more help in that direction, even if it meant a little sacrifice, and thus assist in matters which might prove of very considerable utility. He quite agreed with what Mr. Rees had said—that the higher refractories might come out cheaper in the end even perhaps than silica bricks. If one found a higher refractory which would stand a temperature well over 2,000°, working at 1,600° it would last indefinitely if its other properties were good. It would have the same type of life which a silica fire-brick now had in a re-heating furnace. It therefore did not follow that, because those higher refractories might be costly to produce, they would really be expensive in the end. He was very glad Mr. Rees had put that point of view forward. His own belief was that the future of all such work lay with the higher refractories, and not with the ones which would only just stand up to their job.

Mr. W. J. Gardner said he did not wish to make any criticisms upon the paper, but he did desire rather to attack the Chairman's remarks. When the Chairman said that it was expected, under the new form, that a brick should be made solely of tridymite, and, as the manufacturers could not make it with tridymite, it was therefore a failure, he thought the Chairman was making a statement which could not be substantiated. Mr. Rees had not put forward that statement at all. He did not think that gentleman was so foolish as to imagine that any manufacturer was out for making a tridymite brick, but he believed it was a fact which had already been demonstrated that if the manufacturers could make a silica brick, at any rate with a larger amount of cristobalite in it, with the quartz changing from its alpha-beta state into anything like 75 or 80 of cristobalite, they did get beyond the possibilities of even the very best fireclay materials which were on the market to-day.

With regard to coke ovens, he thought Mr. Rees would agree with him when he said that, if in the walls of a coke oven a lining of silica materials was placed which was highly converted, anything up to 75 or 80 per cent., which was not tridymite but cristobalite, results would be obtained from that lining which would confer much greater benefits than those which would be derived from the very best fireclay lining that had ever been produced.

With regard to Mr. Darling's difficulty in getting a single refractory made up to a specified shape, he did not think the point of view of the manufacturer was quite appreciated. Manufacturers were sometimes asked to make impossibly small and intricate things for experiment. Only that afternoon a firm in his immediate district in Yorkshire had asked him to make them some cast-iron pipes in silica! He had better not mention the name of the firm, because it had been before the British public for quite a long time. They had asked him to quote for some piping in silica which was absolutely the prototype of a cast-iron pipe which was usually made by Newton Chambers. There was to be a flange similar to that seen in gas pipes; the diameter inside was to be 3 to 4 inches; the pipes were to be 9 ft. long, and were to have a junction, and probably at the finish the order would have been for about six of those pipes. The cost of the mould and the work entailed in making those pipes would have been enormous. If, however, manufacturers were approached in the right way, and were told in a straightforward manner that the things were required for experimental purposes, although there might be no commercial advantage in it, he was certain that they would be only too willing to give every assistance in the matter.

Mr. Walter C. Hancock remarked that it was about ten years ago since he had had the pleasure of reading before the Society a paper entitled "The Physical Properties of Clay," and it was astonishing to see the enormous advances which had been made since that time in the scientific examination of refractory materials. There were very few points in the paper on which he could offer any criticism. The paper was extremely sound all through, and considering the time at his disposal, the author had covered a tremendous amount of ground. He noticed in one of the tables which the author gave that there were increasing temperatures at which the bricks were re-fired, and he had noticed the increased resistance to compression. That opened up a question of the greatest interest in the actual manufacture of refractories, namely, whether it was always satisfactory to turn out material from the works with a single firing, and whether it might not be advisable to subject them to a second or even a third, because it was known conclusively that the properties of the material were widely affected by re-heating. The table which the author gave of the effect of the coal ash upon silica bricks, was one which, at the present time, should attract a considerable amount of attention. It was well-known that coals were now being used in this country with a very much higher proportion of ash than had been the case some years ago, and the whole question of the chemical effect of the fuel ash on the refractories concerned was one of increasing importance at the present day. In the particular case which the author

cited, the effect upon the refractory was most marked under reducing conditions, and probably the explanation of that lay in the fact that the refractory which was more affected was the one with the higher content of iron; and under reducing conditions one came up there against one of the greatest enemies of the refractory manufacturer and user, namely, the production of a fusible ferrous-silicate. The whole question of the relationship between the refractory on the one hand and various materials of furnace charge on the other was one which was sufficient to tax the ingenuity of almost any chemist who attacked it, because the secondary products formed were also extraordinarily complicated in their re-action with the original refractory.

Mr. J. Holland said it struck him that the most important part of the paper was that in which the author put forward the suggestion that it would be in the interests of the refractories industry if there was closer co-operation between the user and the manufacturer. He himself spoke purely from a manufacturer's point of view. It had been said that sufficient progress had not been made in the manufacture of refractories. He maintained that the manufacturers of refractories had made infinitely more progress than had the users of refractories, and that while manufacturers had taken advantage to a very large extent of the scientific knowledge which had been placed before them in the last seven or eight years, users had not availed themselves of that knowledge. What was required was that the author and his colleagues should go round the steel works and do a little missionary work, and tell the people how to use the remarkably good stuff which they were getting to-day. Mr. Darling had referred to the bonding of zirconium silicate. He believed there were innumerable patents in Germany for the bonding of zirconium silicate, but it was not the bonding of zirconium oxide or any zirconium bonding that mattered. That was only part of the matter. The principal thing was the burning. In addition to the bonding of the material, it had to be burned right. There was no difficulty whatever in bonding zirconium silicate, but there was a very big difficulty in burning, and there was a bigger difficulty in burning one or two pieces, because if one was going to burn a few pieces of zirconium silicate one had to spoil 19,000 other pieces in order to do it. There was no manufacturer of refractories who was not willing to do all he could to help research. It was to everybody's interest to help research, but when a manufacturer was asked to do a certain thing, from which he would get possibly 3s. 6d., and which might cost him £13 to do it, he asked himself whether he could possibly undertake it. No private individual could help research at such a sacrifice as that. Therefore, it was up to everybody interested in the subject to help forward the British Research Association which was now a very live body. Anyone interested in refractories should take an interest in the Refractories Research Association, as it was only by an Association of that description that research men could get what they required, and that the industry, which was a basic industry, could continue to prosper.

Mr. John Armstrong enquired of the author, with regard to his proposition to line coke-ovens with silica bricks, how did that act when one was using wet sludge from the washeries? Did it affect those silica bricks in the same way as it did fire-clay bricks? He remembered that some years ago he had visited some coke ovens and had seen some first-class fire-clay blocks taken out of the oven, where they had been subjected to wet coal, and they had been all cracked on the surface, like a crocodile hide. The cracks were sometimes an inch in depth. They had been taken out from the bottom of the ovens. He had been wondering if the same effect would not be produced in course of time upon silica bricks. He had been a furnace designer for the last 30 years, and he had come across some badly designed furnaces. He thought it was not the manufacturer of the refractories who was altogether to blame: it was sometimes the builder of the furnaces who used the refractories very badly. One of the chief causes of difficulty was the use of an inferior kind of fire-clay for bonding the bricks together. He had seen first-class fire-bricks put into a furnace, but they had been practically washed out of the furnace owing to inferior fire-clay having been used to bond them together. He sympathised with Mr. Darling's complaint about not being able to get things made to order. He had found the same difficulty himself. He remembered having made an invention for putting wire inside glass, but he had not been able to get a specimen made in Great Britain. In the end he had had to take a glass works himself and make the specimen. One bar to scientific progress in this country was the difficulty experienced of manufacturers not helping the scientists.

Mr. G. M. Gill said as a user of refractory material, he quite agreed with the author in his remarks about the need for co-operation between the manufacturer and the user, but he must say that in his 20 years' experience in gas works he had never had a request made by any manufacturer to be allowed to come and see his material pulled out. Any manufacturer would be welcome in any gas works in order to see how his material stood in actual use. For many years the material used in gas works had not been good enough for the work it had to do. He did not say that that was the fault of the manufacturer; but there was no doubt that in gas works

what was wanted was something which would stand a higher temperature under load. Many of the tests which had been quoted referred to refractoriness, and that was not under load, which was, he thought, very deceptive, because one saw very high figures stated, and the user put the materials in thinking they were going to stand his working temperatures, but his working temperatures were for refractories under load, and such refractories would have to stand in the modern gas works about 1,370°C. Quite a lot of material used in gas works to-day would not stand up to that; it shrank greatly owing to after-contraction and to softening under load. What was wanted was a much larger quantity of material which would stand working temperatures of 1,370°C under load. Quite three-fourths of a retort setting needed that class of material. He would like to ask the author what was the best material for the linings of furnaces where the material came in contact with clinker tools at reasonably high temperatures and where a good deal of clinker formation was experienced.

MR. W. TEMPLE GARDNER said the last speaker had mentioned the question of refractory materials under load. He could say from his experience that there was hardly a fire-clay brick in this country to-day which would stand a temperature under load of more than about 1,300° C. continuously; that was, when the whole brick was heated throughout its length, breadth and height. Semi-silica materials would stand up to about 1,400° C., and straight-lined bond silica materials would stand 1,500° C. and above. Mr. Darling had raised the question of the effect of the glaze on the surface of refractory materials. He thought the special reference had been to the use of the ash from powdered fuel. He had had a certain amount of experience in that direction, and he could say that the two chief factors were the composition of the ash and the temperature. He had known straight fire-clay bricks stand temperatures up to 1,500° C. and 1,600° C. in the presence of fluxed fuel ash, when an elevation of, say, 100° beyond that temperature would result in the complete destruction of the brick due to the solution of the brick in the molten fuel ash, whereas at 100° lower the ash would form a glaze on the surface of the brick and protect it from further attack. With regard to the bonding of zirconium silicate, the best bond was the natural impurity in the zirconium silicate, *plus* a good high temperature for firing. If the bricks were fired to a moderate temperature, say, 1,300° C., then the bond did not fuse or give a strong brick. At 1,400° one got a fairly strong brick, but one wanted to get round about 1,600° before one brought out the fluxing properties of the impurities, and then one did really get a strong brick from zirconium silicate.

THE AUTHOR, in reply, said he had, perhaps, been rather definite in his statements with regard to the use of silica bricks in coke ovens, but the American practice had shown definitely that silica brick was a satisfactory material for the building of coke ovens. Recent German experience had shown conclusively that the silica brick was a satisfactory material for the building of coke ovens for coking salty coals, washed coals and wet sludges. Experimental work which had been conducted on a large scale in this country, where repairs had been made in existing ovens—repairs made in silica—had demonstrated conclusively that the silica brick did what it was claimed it would do.

Mr. Darling had asked how one would select bricks for powdered fuel. The important factors were first of all the design of the particular type of furnace; secondly, the composition of the fuel ash; and thirdly, the exact temperature at which the particular powdered-fuel furnace had been working. He had himself been surprised at the high temperatures which were obtained underneath the arch of an efficient Babcock boiler. A few months ago he had measured with an optical pyrometer temperatures in the arch of a Babcock boiler, and right in the centre of the arch the temperature of that efficient furnace was over 1600°C., and that temperature was maintained continuously. A question had been asked as to the melting point of the bonding of zirconium silicate. That had already been answered to some extent. The melting point was well over 2,000°C. He himself had found that quite satisfactory bonding could be obtained by the use of a slightly impure zirconium silicate. The most satisfactory bonding with zirconium silicate was obtained by bonding with exceedingly finely ground zirconium silicate—quite an impalpable powder—and then firing at a high temperature. The temperature of the firing must be, under those conditions, exceedingly high, certainly over 1700°C. Then mechanically strong articles could be made. The question as to coke ovens and wet slack he had answered. Silica bricks were certainly not more affected by the water dripping from wet slack than the best of other types of coke oven brick. In comparing coking conditions in this country and America, in America the coking was mainly all dry coal coking whereas in this country it was mainly wet coal coking. So far as observation went, and experiment indicated, the properly made silica brick withstood those rather severe conditions in the coke oven, coking wet slack quite well. It depended altogether upon the constitution of the silica brick. Mr Gill had referred to the use of material in gas works. There was no question at all that for efficient modern gas works practice silica was the ideal refractory, provided the silica was properly made and properly burned. He had not much hesitation

in predicting that within a measurable time—within the next generation at least—the majority of gas works would be no longer conservative but would have gone over to the use of that highly efficient material.

OBITUARY.

Lord Sanderson, G.C.B.—Lord Sanderson, whose death took place on the 21st inst., at the age of 82, was a very old member of the Society, having been elected in 1879 under interesting and unusual circumstances, which he mentioned in his first address as Chairman of the Council. He could not, he remarked on that occasion, refrain from expressing his gratitude to Edward Henry, fifteenth Earl of Derby, a former Vice-President, who, knowing the propensity of his private secretary for science, and being desirous, as he said, of making an additional donation to the funds of the Society, proposed Mr. Sanderson for membership and paid his life subscription. Lord Sanderson took a deep interest in the Society's proceedings. In 1910 he was elected a member of the Council; in the following two years he served as Chairman; in 1915, as a Treasurer, and thenceforward up to the time of his death he continued to be a Vice-President of the Society, attending the meetings of the Council as long as the state of his health permitted him to do so, and frequently presiding at meetings of the Society and taking part in the discussions.

Thomas Henry Sanderson was born in 1841 and educated at Eton. At the age of 18, he entered the Foreign Office as a junior clerk. He soon attracted the notice of his superior officers by his conscientious devotion to his duties, by his sound judgment, his diplomatic skill, and the reputation for Foreign Office lore which he soon began to acquire. In consequence of these gifts he was selected for much special work; thus he was attached to Lord Wodehouse's Special Mission to the King of Denmark in 1863-4; he was Assistant Protocolist for conferences on the Affairs of Denmark, and on the Black Sea; he was private secretary to Sir Henry Layard in 1866; Assistant Agent of H.M. Government at Geneva in the arbitration on the Alabama claims in 1871, and private secretary successively to the then Earl of Derby and the late Earl Granville whilst they were Secretaries of State for Foreign Affairs. In 1885 he was appointed Senior Clerk of the Foreign Office, and in 1894 permanent Under-Secretary of State for Foreign Affairs, which post he held until his retirement in 1906.

In recognition of his public services, Mr. Sanderson was made K.C.M.G. in 1887, K.C.B. in 1893, G.C.B. in 1900, while in 1905 he was raised to the peerage as Baron Sanderson of Armthorpe. In 1907 the University of Oxford conferred on him the degree of D.C.L. He did much useful work in the House of Lords, and in 1909 he was appointed Chairman of the Committee on Indian Emigration to the Crown Colonies.

No one who ever met Lord Sanderson could fail to be impressed with his unfailing courtesy and kindness. During his long and varied career he had met with many men whose names are now historical, and his conversation was enriched with graphic descriptions and amusing anecdotes of them. Those who had more intimate acquaintance with him also knew that his benevolence was as great as his courtesy, and that he was always ready to help any one in difficulties even at considerable cost and trouble.

MEETINGS OF THE SOCIETY

Ordinary Meetings.

Wednesdays at 8 p.m., except where otherwise stated :—

April 11 (at 4.30 p.m.).—Edward Parnell, "Sarawak: its Resources and Trade." Capt. Bertram Brooke, Tuan Muda of Sarawak, will preside.

April 18 (at 4.30 p.m.).—Hal Williams, M.I.Mech.E., M.I.E.E., M.I.Struct.E., "Modern Abattoir Practice and Methods of Slaughtering." W. Phené Neal, Alderman of the City of London, late Chairman of the Cattle Markets Committee of the Corporation, will preside.

April 25 (at 4.30 p.m.).—Conference on "The Milk Question." Short papers will be read as follows:—(1) Professor R. Stenhouse Williams, M.B., B.Sc., L.R.C.P. and S.E., D.P.H., "The Arguments for Maintaining an Open Market for Fresh Milk;" (2) Professor J. Cecil Drummond, D.Sc., F.I.C., "Changes in the Digestibility and Nutritive Value of Milk induced by Heating;" (3) S. S. Zilva, Ph.D., D.Sc., F.I.C., "The Effect of Heat on some Physiological Principles in Milk." A Demonstration of some of the Chemical Changes in Milk on Heating to various Temperatures will be given by Captain John Golding, D.S.O., F.I.C. and Mrs. A. T. R. Mattick. M.Sc. The Right Hon. F. D. Acland, M.P., will preside.

May 2.—Maurice Drake, "The Fourteenth Century Revolution in Glass Painting."

May 9.—William Arthur Bone, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Recent Developments in Surface Combustion."

May 16.—

May 30 (at 4.30 p.m.).—A. J. Sewell, "The History and Development of the Perambulator and Invalid Carriage."

Indian Section.

Friday afternoons.

April 6, at 4 p.m.—Geoffrey Rothe Clarke, C.S.I., O.B.E., I.C.S., Director-General Posts and Telegraphs, India, "Postal and Telegraph Work in India." Lord Montagu of Beaulieu, K.C.I.E., C.S.I., will preside.

June 1, at 4.30 p.m.—Austin Kendall, I.C.S., rtd., "The Indian Section of the British Empire Exhibition, 1924."

June 15, at 4,30 p.m.—Sir John H. Marshall, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture.)

Dominions and Colonies and Indian Sections. (Joint Meeting.)

Friday, April 20th, at 4.30 p.m.—Sir Richard A. S. Redmayne, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S., "A Review of the Base Metal Industry, with Special Reference to the Resources of the British Empire." The Rt. Hon. Lord Emmott, G.C.M.G., G.B.E., will preside.

Cantor Lectures.

Monday evenings, at 8 o'clock.

E. Kilburn Scott, Assoc., M.Inst.C.E., M.I.E.E., "The Fixation of Nitrogen." Three Lectures. April 9. 16, 23.

Syllabus.

Lecture I.—Fixed Nitrogen requirements for fertilisers, dyestuffs, and explosives; Pre-war and war developments; Competition with Chili nitrate. Electric Arc Process. Work of Cavendish, Rayleigh, Crookes, etc.; Types of furnaces; Plants in Norway, Switzerland, etc.; Nitrate of lime, Nitrate of soda and special products.

Lecture I.—Calcium cyanamide process. Work of Frank, Caro, etc.; Electric furnaces for Calcium carbide, etc. Methods of preparing pure nitrogen; Plants on the Continent and in America; Products: Ammophos, ammonia sulpate, ammonia nitrate, etc. Other processes: Hausser-explosion process, cyanide, etc.,

Lecture III.—Synthetic ammonia process. Work of Haber, Le Rossignol, etc.: Methods of making pure hydrogen; Types of catalysts: chrome steel bombs; Plants at Oppau and Merseberg; Employment of extra high pressure by Claude; Products. Oxidation of ammonia. Work of Ostwald, Partington, Parker, etc.; Necessity of platinum catalyst.

Note: During the lectures comparisons of processes will be made and the outlook for the future and possibilities of research dealt with. The following points will also be discussed:—Yields; Efficiencies; First cost of plant; Cost of operation; Amount of Electric power; Possibilities of improvement.

Howard Lectures.

Monday evenings at 8 o'clock.

Stanley S. Cook, "Recent Improvement in Steam Turbines." Three Lectures. April 30, May 7, 14.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

Wednesday, April 4 .. Public Analysts, Society of, at Chemical Society, Burlington House, Piccadilly, 8 p.m. (1) Dr. Stanley White, "Physiological Standardisation." (2), Mr. B. S. Evans, "An Investigation into the Chemistry of the Reinsch Test for Arsenic and Antimony and its extension to Bismuth." (3), Dr. G. W. Monier-Williams, "The Estimation of Boric Acid in 'Liquid Eggs,' and other Foodstuffs."

Thursday, April 5 .. Auctioneers' and Estate Agents' Institute, 34, Russell Square, W.C., 6.30 p.m. Mr. Arthur H. Davis, "London's Laws and Bye-Laws."

Friday, April 6 .. Transport, Institute of, at Institution of Electrical Engineers, Victoria Embankment, W.C., 5.30 p.m. Messrs. C. Bentham and J. Rostern, C.B.E., "The Influence of Transhipment on Railborne and Road Traffic, with special reference to the most economical methods of Labour-saving Appliances."

Philological Society, at University College, Gower Street, W.C., 5.30 p.m. Professor W. A. Craigie, M.A., LL.D. (Dictionary Evening).

Metals, Institute of (Sheffield Local Section), at University of Sheffield, 7.30 p.m. Annual General Meeting and paper by Professor F. C. Thompson, "The Heat Treatment of Non-Ferrous Alloys."

Marine Engineers, Institute of, at 85/88, The Minories, E., 6 p.m. Annual Meeting.

Mechanical Engineers, Institution of (Yorkshire Branch), at Philosophical Hall, Leeds, 7.30 p.m.

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FRIDAY, APRIL 6, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICES.

NEXT WEEK.

MONDAY, APRIL 9th, at 8 p.m. (Cantor Lecture.) E. KILBURN SCOTT, Assoc.M.Inst.C.E., M.I.E.E., "Nitrogen from Air." (Lecture I.).

WEDNESDAY, APRIL 11th, at 4.30 p.m. (Ordinary Meeting.) A paper on "Sarawak: its Resources and Trade," by EDWARD PARNELL, late of the Sarawak Civil Service, will be read by COLLINGWOOD HUGHES, M.P. CAPTAIN BERTRAM BROOKE, Tuan Muda of Sarawak, will preside.

INDIAN SECTION.

FRIDAY, APRIL 6th, 1923; LORD MONTAGU OF BEAULIEU, K.C.I.E., C.S.I., in the Chair.

A paper on "Postal and Telegraph Work in India," was read by MR. GEOFFREY ROTHE CLARKE, C.S.I., O.B.E., I.C.S., Director-General, Post and Telegraphs, India.

PROCEEDINGS OF THE SOCIETY.

INDIAN SECTION.

FEBRUARY 16TH, 1923.

SIR EDWARD A. GAIT, K.C.S.I., C.I.E., Ph.D., Member of the Council of India, in the Chair.

THE CHAIRMAN announced that the author of the paper to be read, Mr. Marten, was in India. In his absence, Mr. L. Middleton, I.C.S., who worked with Mr. Marten in the census operations in the Punjab, had kindly consented to read the paper.

The paper read was :—

THE CENSUS OF INDIA OF 1921.

By J. T. MARTEN, M.A., I.C.S.,

Census Commissioner for India.

INTRODUCTION.

1. It is with some diffidence that I have accepted the invitation of the Royal Society of Arts to present a paper on the Census of India in 1921. I am conscious that there is little of interest that I can add to the very full account of the organisation of the Indian Census given by Sir Edward Gait in his paper read before the Society on March 14th, 1912.* That system, devised and perfected under the administration of previous Census Commissioners, is now practically standardised, and it would only weary the Society if I were again to describe it in detail. Nor is it possible at this stage, when the provincial tabulation is incomplete and the analysis of the provincial figures by the local officers not yet available, to give anything more than a very general outline of the results of the census. I propose, therefore, to assume that the Society is familiar with the general method by which the enumeration of the people of India is carried out and to confine myself to a very brief recapitulation of the main points of the Indian system of enumeration and tabulation. I will then try to give some account of the special difficulties and obstacles that we have encountered on the present occasion, some idea of the lines on which we have attempted to direct the census of 1921 and some estimate of the accuracy and value of the information we have obtained.

GENERAL FEATURES OF THE DECADE.

2. Before considering the methods and results of the census, it may be interesting to recapitulate the principal influences which have, during the decade, affected the life of the people of India. The earlier half of the decade was free from any intense and widespread scarcity of food crops. The monsoon had several times given cause for anxiety, but except over limited areas the rain did not fail to fall at the last in sufficient quantity to give at least a fair harvest of the principal crops. The wheat and rice crops of the first two years were

*Journal, March 29, 1912, p.501.

well up to the average. In 1913-14 and 1915-16 the rain was not so well distributed and there was some local scarcity in the north and the west of India. The year 1914-15 was favourable to wheat, but not so favourable to rice, while in 1916-17 and 1917-18 both these staple crops were exceptionally good, giving a large outturn on a full acreage. Cotton and jute, the principal mercantile crops, were both below the average in 1913-14 and 1915-16, but in the case of these crops the higher prices obtainable in a poor year tend to recoup the grower in value for what he loses in quantity. Meanwhile, the economic conditions in India were gradually undergoing a change. The outbreak of war in 1914 caused an immediate decline in the bulk of India's foreign trade by the contraction of shipping. The influence on prices was not felt severely during the first two years of the war, fair harvests and full stocks keeping the prices of foodstuffs from any considerable movement. In 1917, however, the conditions of India began to respond to the world disturbance of the war. Men for the fighting and labour units, and food, munitions and war material of all kinds to back them were demanded. The strain on the railway organisation dislocated the local markets and the distribution system in the country began to give trouble, while the rising prices of imported necessities, such as salt, oil and cloth hit the poorer classes severely. The harvests of 1917 were good, but the year was wet and unhealthy and a virulent outbreak of plague in the north and west of India caused heavy mortality. Wages had not yet begun to move with the upward movement of prices, and there was a general feeling of restlessness among the labouring classes which rapidly increased under the influence of political propaganda. Then followed the disastrous seasons of 1918-1919. The deficient and ill-distributed rains of 1918 caused a crop failure as bad as, if not worse than, that of 1900, and prices of foodstuffs, cloth and other necessities of life soared to heights never previously reached. Famine relief organisation is now so highly perfected in India that scarcity is not necessarily accompanied by high mortality; but India was not to escape, and the influenza epidemic starting in the latter part of 1918 visited almost every portion of the country and wiped out in a few months practically the whole natural increase in the population for the previous seven years. Emergency measures were taken. Transport, the export of foodstuffs and the distribution of the necessities of life were all placed under Government control, and it was only the wonderful resisting power of the people acquired from years of steady economic improvement that enabled the country to tide without absolute disaster over a year of unprecedented difficulty and strain. The good harvests of 1919 caused some alleviation, but prices still remained high and an unsatisfactory monsoon in 1920 caused a prolongation of distress in some of the central and western tracts of the country. It was not till the end of 1920 and the beginning of 1921 that prices gradually began to come down. Meanwhile, the strain and stress of the last few years had given rise to political, social and economic disturbance in all strata of the population, which manifested itself on the one hand in the form of political agitation, intense racial and class feeling and a growing restlessness in the lower and labouring classes, and on the other hand in the more objective form of strikes, riots and resistance both active and passive to constituted authority.

The Method of Enumeration.

3. Even this brief review of some of the conditions of the decade has, I am aware, taken us somewhat outside the scope of our immediate subject, the census of 1921, but the circumstances of the census organisation, the interest of the figures which resulted from it and the problems which they suggest are intimately bound up with the condition of the people, their standard of life and their level of intelligence. I will remind the Society that, as in the United Kingdom so in India, we attempt a *de facto* enumeration of the people as far as possible on a particular day and in the place where they are on that day. Each province and each of the larger Indian States carries out the enumeration of its own territory, the tabulation of the figures and the compilation of the local census report through the agency of a specially appointed officer acting under the general direction of the Census Commissioner for India. Within the 21 provinces and states which formed in 1921 the independent units of census administration, the local responsibility for the enumeration rests with the head of each district, acting under the orders of the Provincial or State Superintendent of Census Operations. The district itself is divided

into census charges, circles and blocks, each with its own officer, the block, consisting of about 30 or 40 houses, being the ultimate unit of the scheme, since, owing to the general illiteracy of the Indian population, the employment of the householder as the enumerator of his household must, except to a very limited extent, be for many years impossible. If we assume that each block, *i.e.*, each enumerator's charge, consists of 150 to 200 persons, we get, apart from the supervising officers, a staff of something near two million enumerators in the whole of India. Now, while a fair proportion of the supervising staff consists of officials the enumerators are almost entirely non-officials. They are impressed into public service for the purposes of the census and placed under statutory obligation to perform certain duties. They are required to fill up the schedules for their block some weeks before the census date and to revise them on the census night. They receive instruction, help and supervision from the superior staff, but, save in exceptional cases, they receive no remuneration. It is clear that the accuracy of the entries in the schedule depends largely on the ability of the district officials to secure a willing and trustworthy body of enumerators and an efficient check on their work. It is obvious that the statutory obligation, in the case of so large a body of unpaid workers appointed for a short period for work to be performed in a definite and limited time, can with difficulty be enforced. The enumeration, therefore, largely rests on more or less voluntary co-operation. In the words of one of the provincial census officers, "Our census system is almost patriarchal in form. It conceives of unlimited numbers of ready and willing workers who will sit in a ring round the man above them, while he teaches them their work, and will afterwards faithfully carry out the instructions given them." It is at this point that the census organisation of 1921 came in touch with the new conditions of social and political feeling which have been taking more and more definite shape during the last few years.

Special Difficulties Met With.

4. I do not propose further to analyse the causes of the change of outlook which has certainly come over a considerable part of the Indian people. Economic, social and political factors have, as we have seen, all been at work. The result with which we are concerned is a distinct weakening of the old feeling of discipline on the part of those who are directly or indirectly connected with the administration, together with the growth of a spirit of individual independence in every class of the population which has been brought into contact with modern conditions. The non-co-operation movement and labour strikes are some of the direct expressions of this change of sentiment in its most pronounced form, and had in the case of the census organisation to be met by definite action. But apart from these forms of direct obstruction there was, over a much larger area, a distinct disinclination on the part of that section of the population on whom the census relies, the lower literate classes of the towns and larger villages, to take up without remuneration work which demanded a certain amount of time and entailed a certain amount of trouble and inconvenience. Our more definite obstacles in the form of strikes and direct refusal to co-operate occurred chiefly in the west of India (the Bombay Presidency) in Calcutta City and in some of the cities, towns and larger villages of the Punjab, the United Provinces and the Central Provinces. At a critical time a large section of the village accountants of the Bombay Presidency, who constitute a very important element in the census organisation, went on strike for higher pay and refused to take on duties in connexion with the enumeration. Similar strikes on the part of the Land Record staff occurred in other provinces, while the schoolmasters of village schools, another body of men ordinarily available for the enumeration, were in a state of extreme dissatisfaction at their pay and prospects. The enumerator's life is in any case not always an easy one. We had a case where an enumerator was stabbed by an infuriated member of one of the lower castes, who considered him too inquisitive. Another was severely beaten because he refused to make an obviously false entry regarding the caste of a certain community which was ambitious of a higher status in society. In portions of Calcutta the enumerator is apt to meet with an unpleasant and aggressive rudeness from the *goondas* or bazaar bullies. In many of the larger towns the greatest difficulty was experienced in obtaining a sufficient staff of enumerators and supervisors. The vernacular Press, while advising that information should not be withheld

by the general public for filling up the census schedules, declared that all voluntary assistance in the way of acting as enumerators should be refused, and though Mr. Gandhi announced at the last moment that no obstacle should be placed in the way of the census operations it was too late for this pronouncement to have much effect and throughout the Bombay Presidency and elsewhere the spirit of the non-co-operation movement afforded those designated for census work just that excuse which they required for shirking a duty which they had from the first been anxious to avoid. Difficulties of this kind had to be dealt with by a district staff already fully occupied with extra work in connexion with the elections to the legislative assemblies and with the many new political, economic and local problems which the state of the country presented.

The Accuracy of the Census.

5. It is perhaps premature to form at this time, before the figures have been analysed in detail, any final opinion as to the comparative accuracy of the enumeration. We have, however, I believe, obtained a census which is not less accurate than previous enumerations in respect of the number of persons included, and throughout the Indian States and over a very large rural area of British India, which is little affected by the advanced trend of opinion, the schedules are at least as accurate as they were in the previous census. But it must be admitted that in the not inconsiderable areas in which the difficulties of obtaining and training the staff were pronounced a certain proportion of the schedules are carelessly and inaccurately written up. In some cases it has been possible to revise defective schedules after the census, but this has not been feasible in all cases. It will be the task of the Census Superintendents to form as full an estimate as possible of the extent to which these imperfect schedules affect the general value of the compiled figures. I have dwelt on these features of the 1921 census organisation because to those who are familiar with the conditions of the Indian census it is obvious that they are of essential importance. The difficulties that we met on the present occasion were, I believe, in most cases successfully overcome. We doubled up our blocks. We called up official assistance wherever it was available. We increased the number of paid enumerators and in some cases had to dispense with the final check on the census night and rely on our preliminary enumeration. But what of the future? Apart from temporary political causes of a specific kind can we expect in future years, except perhaps in the more backward rural areas, a successful enumeration from an organisation based on practically voluntary work? If not, will India foot a bill for the census which shall provide an adequate remuneration for the enormous body of workers involved, or must we perhaps change the method of the enumeration and adopt in place of our *de facto* census something on the lines of the American system, which relies on a limited number of workers highly trained for their duties and paid for their services?

The Scope of the Census.

6. Our schedule on the present occasion followed closely the lines of that of the last census. We asked for sex, age, civil condition, religion, caste or race, occupation and secondary occupation, language, birthplace, literacy and certain infirmities. In view of the immense amount of valuable research in the realms of ethnography and language carried out in connexion with the Ethnographic and Linguistic Survey, it was decided that, except where there were special reasons, *e.g.*, in Burma, for continuing ethnographic and linguistic research, it was unnecessary that the collection of information on these subjects which does not bear directly on the statistics should form a prominent feature of this census. On the other hand. the tradition that the scope of the Indian census should extend beyond the mere collection and presentation of statistics was not lost sight of and it was thought that special attention might be given to the collection of statistical and general information bearing on the industrial and economic side of the life of the people. Religion must always form an important part of the Indian census questionnaire, and some of the principal sects, *e.g.*, sects of Christians and the religious divisions of Mohammedans have a special interest from various points of view. Apart from the communal and administrative value of the statistics, religious distinction forms the basis of social and even racial customs which are vital factors of the growth of the population. The value of the entry of caste is perhaps a more arguable matter and a

resolution for its omission from the schedule was actually put down for discussion in the Imperial Legislative Assembly, but was dropped in the absence of the mover. Even, however, if we disregard its ethnological interest caste still forms the basis of social, political and economic distinctions and in correlation with other statistics is the chief clue to the differences in the various strata of society. It is mainly from these points of view that we propose to treat the caste statistics on the present occasion. An interesting indication of the position of caste and the modern Indian attitude towards it may be obtained merely from an account of the difficulties attending the collection and classification of the statistics, while important political and sociological problems are linked up with the larger social divisions of the Hindu population, the Brahmans, the non-Brahmans and the untouchable classes.

Industrial and Economic Enquiries.

7. The development of Indian industries and the distribution and supply of labour are problems which demand the accumulation of relevant statistics of all kinds, and it was thought that a considerable development of the kind of enquiry started in 1911 by Sir E. Gait in his special industrial schedules might be possible. We consulted the Industrial Departments both at headquarters and in the Provinces, and it was decided that the time for any ambitious programme of statistical enquiry in this direction had not yet come. The Industrial Department was yet in its infancy. The ordinary district staff available for census work was fully occupied with administrative work of all kinds. Anything on the lines of the most modest census of production would require a trained staff, for which neither the opportunity nor the funds were available. We have, however, enlarged the industrial questionnaire so as to show more fully the character of the personnel of all kinds employed in organised industrial undertakings, and we hope to collect by more detailed tabulation some useful statistics showing the character, distribution and movement of labour generally. Proposals had been put forward for something of the nature of an economic survey to be carried out in connexion with the census. Here, again, we found that it would be impossible to obtain the necessary assistance from local officers or the necessary staff to carry through the work properly and the scheme had to be dropped. But the economic condition of the people and their standard of life is intimately bound up with questions of population, and it may be possible to provide material for some more detailed discussion of the question of the pressure of population on the present resources of the country. Mr. Wattall's interesting and well-written little book on this subject, based on the figures of the previous census, is doubtless familiar to members and forms a useful text for the treatment of the population problem in India. We have a population with very considerable natural capabilities of increase. That increase is checked by ignorance of and indifference to maternal and infant welfare, by occasional famines and by epidemics, such as malaria, plague and influenza. We endeavour year by year to minimise the effects of these checks. What if our endeavours should be successful? Can India support a considerable increase of population in the future under any conditions that seem likely to arise? If not, which is to lead the way to economy, the birth-rate or the death-rate, and will the other follow? In this connexion we have made some tentative efforts to collect in some provinces, where circumstances seemed most suitable, on special schedules some statistics of the size and sex constitution of families in different social strata, with a view to obtaining information as to the normal fertility of married couples. The attempt is beset with difficulties. We cannot, as a rule, obtain information direct from the women, and returns of age and duration of married life are often vague and unsatisfactory. We can only accept returns where the information is likely to be fairly accurate and yet too careful a selection may vitiate the sample. Such attempts, however, are worth making, provided that the limitations under which we are working are fully recognised in reviewing the statistics.

Tabulation.

8. At the last two censuses of India the slip method was used for the tabulation of the statistical information obtained in the schedules. The possibility of introducing the system of mechanical tabulation for the present census was carefully considered. The objections to it for the Indian census under the present conditions are weighty and, in my opinion, conclusive. We have to

deal with a heterogeneous population of over 300 millions scattered over a very large area. Our census staff in each of the twenty-one units of administration is appointed for the occasion and is not linked up with any permanent statistical office. Nor have we any experience in India of mechanical tabulation. Even if we could obtain the number of machines required to distribute over the twenty-one provinces, which is very doubtful, we should have to provide a trained staff to work the machines and mechanicians to look after them. On the other hand, if we concentrate the tabulation at two or three centres, say, Calcutta, Bombay, Madras and Rangoon, we may have less difficulty in regard to the supply and working of the machines, but we have to face even more serious obstacles. Our schedules are written in many different languages and record the life history of all kinds of peoples. We are continually called upon during tabulation to solve problems which require local knowledge and experience, to make references to districts on doubtful points and even at times to attempt the reconstruction of schedules which are imperfectly written up. All this would be impossible if we take the schedules outside the local areas. Another serious objection to the mechanical system lies in the provision of cards for the machines. At present the only satisfactory card obtainable comes from America. We have sufficient difficulty in working our contracts in India for the supply of paper for our huge population. Even if we could get all the entries required for each person into one card, a doubtful proposition, we should require 350 million cards for our machines and should be dependent for their supply on a country at the other side of the world. I think there is no doubt that in our present system, so long as we can obtain fairly cheap clerical labour in the local offices, we have, on the whole, the cheapest, most trustworthy and most expeditious method that it is possible to devise for dealing with our statistics in India. A department that is constituted at a particular time for a limited period cannot make elaborate experiments, and it must be left to more permanent offices to prove the value of these machines in India. We have not, however, been free from difficulties of our own in connexion with our tabulation. We have had to deal with strikes in the offices in Madras, Bengal, the Central Provinces and elsewhere. We have also had, in Karachi and Patna, for example, definite cases of non-co-operation in the shape of the destruction of slips and the malicious fudging of entries. Considerable delay has resulted on this account in the issue of the final figures of population by districts, towns and religion, and the compilation of the tables has been further delayed in some provinces by difficulties and delays in the Presses.

Movement of Population.

9. We may now turn to a consideration of the results of the census. It will be remembered that the census of 1911 showed an increase amounting to 7.1 per cent. for the whole of India and 5.5 per cent. for the British Provinces. The decade which preceded that census was one of recovery from periods of famine and scarcity, but the increase by natural reproduction, which was conspicuous in the Central Provinces, had been unfortunately checked and neutralised in the Punjab and the United Provinces by serious epidemics of malaria and plague, while the gain of population in Burma and Assam, which amounted to 15.5 and 15.2 per cent. respectively, was partly due to the stream of labour flowing on to them from the United Provinces, Bihar and Orissa and Madras. The population of India stands, according to our recent enumeration, at nearly 319 million persons, a gain in the decade of 1.2 per cent., the increase in the British Provinces being 1.3 and that in the Indian States 1.0 per cent. Of the larger British Provinces, Assam shows a rise of 13.3, Burma of 9.1 and the Punjab of 5.7 per cent. The increase in Bengal, Madras and the North-West Frontier Province is between 2 and 3 per cent. in each case. The enclave which forms the Province of Delhi has increased in population by over 18 per cent., the rise being of course due to the development of the Delhi city area. The population of the United Provinces has fallen by over 3 per cent., the decrease being almost equally divided between the two sub-provinces of Agra and Oudh. The population of Bihar and Orissa has declined by 1.4 per cent., the loss in Orissa amounting to 3.2 against a fall of 1.6 in Bihar and a slight rise in Chota Nagpur. In the larger part of the Bombay Presidency the decline is small, but in Sind the fall amounts to 6.7 per cent.

The population of the Central Provinces has made no movement. Of the larger States Hyderabad has decreased by 6.8, the Rajputana States by 6.5 and the Central India States by 2.2 per cent. On the other hand, the populations of Travancore, Kashmir and Baroda have gained by 16.8, 5.1 and 4.6 per cent. respectively, while the States attached to Assam, Bengal and the Punjab show fair increases.

It would be of special interest on this occasion if we could follow the movement of the population in various parts of the country through the intercensal years of the decade. Although the registration of vital statistics in India is not yet sufficiently trustworthy to form a basis for any exact calculations, still these returns are now, especially in rural tracts, good enough to give us some indication of the trend of the population curve during the decade, and the statement (Table B) which I have had prepared will be of some interest from this point of view. The figures given are obtained by simple arithmetical calculation on the basis of the population figures of 1911, and must be accepted as an approximation only to the truth; and it should be borne in mind that as the reporting of births is generally less complete than that of deaths the difference between the births and deaths, or what may be called the survival rate, given by the figures is lower than in actual fact. The figures, at any rate, indicate that the increase in the population shown by the 1911 census figures of most of the larger provinces was sustained and continued during the first seven years of the decade in something resembling the same proportion, so that, in spite of epidemics of cholera and plague, which, however, did not reach the same pitch of virulence as in the previous decade, there might have been a gain of population at least equal to, if not well above, the proportion shown at the 1911 census but for the calamity of 1918, when the upward curve dropped steeply in each province and only in a few recovered at all during the succeeding two years. Assam and Burma are the only two of the larger units in which a substantial increase of population has occurred and both are provinces which attract a considerable immigrant population from outside. In the Central Provinces the whole of the large natural increase, which is a feature of the backward aboriginal people, was wiped out, while the United Provinces again showed a decline of population, a part of which is due to emigration. The factor of migration has, of course, not been taken into consideration in drawing inferences from these figures. So far as the whole of India is concerned migration plays an unimportant part, but it is not at present possible to estimate its exact effect. The number of Indian-born persons connected with the Army outside India at the time of the census was, undoubtedly, larger than usual. On the other hand, the British garrison in India was also larger and there has been for the last three years an entire cessation of labour migration to the colonies and a considerable amount of repatriation of Indian labour from them. It is probable that the difference in the balance of immigrants and emigrants has not substantially changed since 1911.

The Influenza Epidemic of 1918-1919.

10. The factor which has, therefore, dominated the census figures is the influenza epidemic of 1918 and 1919, and some account of this appalling visitation and its effects on the population of India may be of interest. Taking the registration figures for what they are worth, we have, as we have seen, survival rates (excess of births over deaths) varying between 6.5 and 10.6 *per mille* in the period 1910 to 1917, thus showing a steady increase in the population from year to year in the areas under registration. In 1918, the year of the epidemic, the death-rate went up to 62.5 per *mille* of the population, and as the birth-rate dropped at the same time the difference stood at an excess of 27.1 per *mille* deaths over births. Even allowing for special defects in registration in this year, there is no question of the high mortality and the recorded figures in the Central Provinces, where the epidemic was specially virulent, was 102.6 per *mille*, or more than 1/10th of the population, while the death-rate in some of the States of Central India, where there is no registration of vital statistics, was certainly equally high. The survival ratios in the Punjab and the United Provinces were 41.4 and 42.5, respectively, but a part of the difference must be ascribed to defective registration of births in that year. Where exactly the influenza came from cannot be ascertained, but it was first recognised in Bombay in July, 1918, and spread from there eastward and northward over the country in two distinct waves of increasing

intensity, so that by the end of August it was general over India. There is ample evidence that the disease was spread by infection from locality to locality by rail, road and water. The second wave seems to have had its origin in or near Poona in the early part of September and rapidly spread over the country. It was accompanied by very high mortality, due chiefly to pneumonia and respiratory diseases. While the earlier and less fatal influx of the disease seems to have affected most severely the very young and the very old, the later and intenser attack fell most heavily on the adult classes between 20 and 40, the mortality among women being, as a rule, higher than among men. The figures show that the excess mortality in the age categories 20 to 40 amounted to nearly four times the mean. The epidemic was specially fatal to women in pregnancy, and it is suggested that apart from this factor the comparatively higher mortality among women may have been due to the fact that in the ordinary Indian household the women would probably have to continue to the last moment the work of the house and of nursing the sick members, even when themselves suffering from the disease. I can myself speak from personal knowledge of the terrible effect of the epidemic in the country-side, as I was at the time in charge of one of the worst stricken districts of the Central Provinces. It is no exaggeration to say that at the worst period whole villages were absolutely laid desolate by the disease. There was sometimes no means of disposing of the dead, crops were left unharvested and all local official action was largely paralysed owing to the fact that the majority of the official staff were put out of action by the epidemic. In the towns more could be done and every possible form of relief and assistance that could be devised was adopted. But the epidemic took us unawares and the measures so familiar to the people on the outbreak of a plague visitation, such as evacuation of infected houses and localities, were worse than useless and only served to spread the infection. To add to the distress the disease came at a period of widespread crop failure and reached its climax in November, when the cold weather had set in; and, as the price of cloth happened at the time to be at its highest, many were unable to provide themselves with the warm clothing that was essential in the case of an illness that so readily attacks the lungs.

It will be easily understood by those who are acquainted with conditions in India that no accurate statistics of the mortality due to influenza can be available. The reporting and registering staff are not capable of even rough diagnosis and the deaths were simply described in the registers as due either to fever or to respiratory diseases. Various statistical methods have been adopted to estimate indirectly the death roll of the epidemic in 1918, which are chiefly based on comparisons between statistics of that year or part of that year with corresponding statistics of normal years. Without describing these methods in detail I may give the official result arrived at as about 7,100,000 persons. To this must be added over 1⅓ million of deaths in 1919, during which year the disease lingered on with decreasing intensity in many parts of India, and we get a resulting mortality of nearly 8½ millions. It must be remembered, however, that this figure applies only to the areas under registration, which contain little more than two-thirds of the total population of India. The epidemic was specially virulent in the Rajputana and Central India States and in the States of the Punjab, Central Provinces and Bihar and Orissa, while the attack was severe in Kashmir and Mysore and terribly acute in Hyderabad. In fact, the areas for which no vital statistics are available were more severely affected than a large proportion of the registered area, which includes Assam, Bengal and Madras, where the epidemic was fairly light. We should probably have to add a figure of at least four millions of deaths in these areas and thus arrive at a total mortality of at least 12½ millions for India. It is interesting to note that even this conservative estimate of mortality, most of which occurred in the course of four or five months, exceeds by over a million the recorded number of deaths from plague in India, extending over 23 years (1898-1920). But the loss of population did not stop there. The number of actual deaths was, of course, only a fraction of the number of persons who suffered and the low birth-rate of 1918 (35.4) and of 1919 (30.2) are directly due to the debilitated state in which so large a proportion of the population were left by the epidemic.

THE WAR.

11. I have already said something as to the effect of the war on the political, social and economic conditions of the country in so far as it affected the census. The war had little direct effect on the population figures except in so far as the distribution of troops affected the figures of some of the military centres and cantonments. The recruitment of troops and labour corps was spread widely over the northern and central areas of the country. But the Punjab provided the bulk of the able-bodied men, and it is possible that the rise in the proportion of the females to males in that province may be partially due to this fact. The maximum number at any time out of India in regiments and labour corps was about 480,000, but by the date of the census a large number of units had returned and the number of persons outside India who could ordinarily have come into the enumeration was about 126,000. Casualties in fighting and labour units amounted to about 58,000 men. It has been suggested, not without substantial foundation, that the absence of these troops and labour corps from the country actually resulted in a net saving of life since, based on the influenza death-rate in the provinces from which the majority were drawn, the number who would have succumbed to the disease in India is greater than the number who actually died as the result of military operations. It is unlikely that there was any considerable effect on the birth-rate by the absence of men abroad, as leave was given as freely as possible. I made all arrangements with the authorities in Bagdad to take a census of troops and Indian residents and visitors in Mesopotamia, but, owing to the disturbed conditions of the country in 1921, it was found impossible to carry this out. A rough local census held in 1920 showed that there were about 3,000 Indians resident in Mesopotamia in miscellaneous occupations not directly attached to the Army. A good many of these would be railway employees and merchants.

DENSITY.

12. The average density of population per square mile over the whole of India is now 177, that of British Provinces being 226, of the States 101. The maximum density lies in Bengal, where there are (including both rural and urban areas) 608 persons per square mile over the whole area of the Presidency as now constituted, while in certain districts the density rises to over 900. The subject of the distribution of the population and the factors which determine its local density were very fully discussed in the reports of the 1911 census. With the small variation in population disclosed by the recent census the figures for the larger units have naturally not altered considerably and the more interesting features of density cannot be analysed until the statistics of the smaller units are available. The industrial development in certain areas during the decade has stimulated the flow of labour and its concentration in the more important industrial centres, such as the coal-fields in the east and the cotton industries in the west, while the opening out of the great irrigation works in the Punjab has caused a further movement of agricultural population to the new canal colonies. The problem of the pressure of population on food and wealth production is one which is receiving more and more serious consideration at the hands of Indian economists. There are many obstacles in the way of improvement in conditions of cultivation, the ignorance, immobility and conservatism of the agricultural population, the system of land tenure with its progressive fragmentation of holdings and the difficulties connected with the introduction of agricultural machinery. Yet industrial development, even if it be possible, on a large scale in India, cannot take the place of agriculture. The country must produce food for an increasing population or become dependent on the world's food supplies with disastrous consequences. We have had in the last few years the new phenomenon of an import of wheat into India from Australia. India requires much from outside for her development and she must depend for many years on what she produces from the ground to pay for what she must get from other countries.

CITIES AND TOWNS.

13. The proportion of the urban population, which stood at 9.4 per cent. in 1911, has increased to 10.2 per cent. of the whole population at the present census. The impetus given during the last few years to industrialism has stimulated the flow of labour from the country to the towns. The results of our industrial census are not yet compiled, but official returns recently issued show that the number of registered joint

stock companies alone at work has increased from 2,304 in 1911 to 3,668 in 1920. The problem of the industrial towns is becoming a real one and town-planning on up-to-date lines has been engaging a considerable amount of attention and has in some cases considerably affected the census figures. We have extended to some of the larger cities statistical enquiries into the pressure of the population on house accommodation and space which were previously confined to Calcutta and Bombay. Calcutta, with its suburbs, has grown by 4.3 per cent., the population now standing at 1,327,547, but a considerable number of the inhabitants of some of the more congested quarters have moved out into the suburbs, the increase in the Maniktolla and Cossipore suburbs being as much as 25 and 17 per cent. respectively. The population of Bombay is now 1,175,914, which is very little behind that of Calcutta and 20 per cent. above the figures of last census. Bombay is now the centre of a cotton manufacturing industry which bids fair to rival that of Manchester in size and importance. Ahmedabad, in the same presidency, also a large industrial centre, has added to its population in a proportion almost equal to that of the presidency metropolis, and speaking generally, the concentration of population into urban areas is more conspicuous in the western presidency than in any other part of India. In Dacca the new University has brought an influx of residents. In Bihar and Orissa the population of Patna has declined, but Gaya has gained, while in the mining areas has begun, in connexion with the exploitation of coal and iron, a considerable semi-urban concentration of labour, skilled and unskilled, the most conspicuous example of which is the new town of Jamshedpur, which from a village of 5,672 persons in 1911 has risen to a flourishing and well laid-out industrial town of 57,360 inhabitants. Delhi, the capital of the Government of India, is now the fourth largest city in India, coming next after the three presidency towns and taking the place held at the previous census by Lucknow, which has now been outstripped in the race for population by Lahore and Ahmedabad also. Cawnpore and Nagpur, both large industrial centres, have added considerably to their population, while the effect of the redistribution of troops owing to the war is seen in the growth of military centres, such as Poona, Quetta, Peshawar and Rawalpindi. In Burma, Rangoon and Mandalay both show substantial increases. Of the larger towns of the States, Hyderabad, with a population of over 400,000, stands easily first, in spite of a considerable decline during the decade, while Indore, Bangalore and Mysore have all gained population.

Age and Sex.

14. In a population in which death gathers his victims not only by regular systematic pruning, but by intermittent hostile attacks seemingly directed against special groups at different times, there can be no continuous standard of age distribution. Famine and scarcity take off the very young and very old. Plague and influenza seem specially fatal to those in the middle age categories. The influence of each continues as the depleted categories gradually mount up into the higher age periods. The infants and children lost in the great famine period of 20 years ago would have swelled the number now in the wage-earning and reproductive ages. These groups have been further depleted by the ravages of the 1918 epidemic, which seems to have selected its victims chiefly from among those at the working ages. This selection must again react on the birth-rate in the future, especially as the proportion of women in the reproductive ages has noticeably decreased almost throughout India. The difference in the proportion of the sexes is of interest. The number of females per 1,000 males in India, according to our census, is 945, the lowest proportion yet shown at any enumeration of the Indian population. Among the few provinces in which the proportion has risen is the Punjab, where females are always proportionately fewer than elsewhere and were specially in defect at the census of 1911. The number of men absent on military duty can have had little effect on the proportion of the sexes in the totals of the larger units and until the local figures are carefully analysed it is dangerous to hazard anything but general observations on the statistics. We can, however, presume that the effect of the selective influence in favour of females at the famine of 1900 is gradually disappearing, while we know that the high birth-rates of the last decade and the plague and influenza epidemics are all influences adverse to female life. It is curious to notice that the fall in the birth-rate which occurred in the latter half of the decade, *i.e.*, from 1915 and onwards, was

accompanied by a fall in the proportion of females born to males born. All the known influences of the decade have, therefore, been specially unfavourable to female life.

Religion.

15. The census figures show an increase of 3.1, 7.4 and 22.7 per cent. among Mohammedans, Sikhs and Christians respectively, and a decrease among Hindus amounting to .5 per cent. It is well known that the Mohammedans are, chiefly on account of their social customs, more fertile than the Hindus, but apart from this fact there are special reasons why the decade should have been less favourable to the Hindus than the followers of Islam. In the first place, nearly 40 per cent. of the Mohammedans live in Bengal, where the influenza epidemic was less severe than in the rest of India, and there was a fair increase in the general population. Again, the Mohammedan is more of a town dweller than the Hindu, and, as has been seen, owing probably to the greater facilities for medical treatment and relief, the towns escaped with a lower mortality from the epidemic than the rural areas. The tribes who returned themselves as Animists are among those who suffered most acutely in the calamity of 1918, and both on this account and owing to a progressive tendency towards absorption in the Hindu and Christian communities this section of the religious division is substantially reduced in numbers. The noticeable rise in the proportion of Christians from 124 in 1911 to 150 per 10,000 at the present census is partly due to the large increase in the British garrison in India, as is clearly indicated by the figures of the Punjab, United Provinces, and North-West Frontier Province. The substantial increase in the number of Christians in the Madras Presidency, where about three-fifths of the total number of Indian Christians are to be found, has not resulted in any change in the proportion of the Christian community in the population of the Presidency. There are still three Christians in every 100 of the population. The combination of the principal nonconforming Christian communities of South India into one church under the name of the South India United Church, with a congregation of nearly 100,000 persons is an interesting feature of the decade. The Sikh community has made conspicuous progress during the decade in organisation and political self-realisation, but here again the distribution of the figures of variation, which make up a total increase of 7.4 for all India, is largely dependent on the location at the time of the census of the Sikh units in the Indian Army.

Literacy.

16. The return of literacy is always of special interest at each census. The standard fixed in the Indian census as qualifying an individual to be returned as literate is a simple one, namely, that he should be able to write a letter to a friend and read the reply. The proportion who are returned as literate according to that standard at the present census was 1,056 males and 105 females per 10,000 of each sex. Some further details of the progress of literacy are given in the statement appended, from which it will be seen that though the standard in India is in any case low, there has been all-round progress, which, however, varies considerably in different provinces. Burma, where the number of indigenous village schools is large and there is a widespread tradition of literacy, heads the list of Provinces in this respect with a proportion of 576 literate males per 1,000 or considerably more than half the male population. In Bengal and Madras the proportion is about a fifth and in Bombay rather less, while in the States of Baroda, Cochin and Travancore the proportions are 28, 36 and 42 per cent. respectively. What is more marked, however, is the substantial increase in the number and proportion of literate women throughout India. Of females over 20 years of age the number who are literate in India is now 23 per *mille* against 13 in 1911. The proportion is still very low among the more backward peoples of the Central Provinces, Bihar and Orissa, the Rajputana Agency, Kashmir and Hyderabad and in the provinces of Northern India, which contain a large proportion of Mohammedans; but even in such areas it is steadily improving. Female education is a subject which is intensely interesting the more advanced portion of the Indian community and some of the States are giving it special attention. The proportion per 10,000 of women in Baroda, for example, who are able to read and write, has advanced from 205 in 1911 to 403 at the recent census and substantial improvement in the same direction is seen in the figures for Mysore and the States of Cochin and Travancore. In British India the

TABLE A.

Province, State or Agency.	Population in 1921 in millions.	Density per sq. mile	No. of females per 1,000 males.	Number per 10,000 who are: Hindus.	Musalmans.	Buddhists.	Animists.	Christians.	Others	Variation per cent. in Total Population: 1872–1921	1911–1921	901–1911	1891–1901	1881–1891	1872–1881	Variation per cent. in each Religion, 1911-21: Hindu.	Musalman.	Sikh.	Christian.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
India	318.9	177	945	6,856	2,174	366	309	150	145	+54.7	+1.2	+7.1	+2.5	+13.2	+23.2	—.5	+3.13	+7.4	+22.7
Provinces	247.0	226	947	6,606	2,407	465	280	123	119	+33.6	+1.3	+5.5	+4.7	+11.2	+7.4	—.4	+3.5	+9.0	+21.5
1. Ajmer-Merwara	.5	183	837	7,356	2,055	—	96	112	381	+25.0	—1.2	+5.1	—12.1	+17.7	+16.2	—6.6	+25.6	—76.2	+1.8
2. Andamans and Nicobars ..	.03	9	303	3,278	1,515	979	3,387	586	255	—	+2.4	+7.3	+57.9	+6.7	—	—6.9	—10.4	—14.3	+180.2
3. Assam	7.6	143	920	5,434	2,896	17	1,479	168	6	+83.2	+13.3	+14.9	+6.7	+11.6	+18.2	+13.6	+16.7	+31.7	+92.8
4. Baluchistan (Districts and Administered Territories)	.4	8	650	919	8,731	4	—	159	187	—	+1.5	+8.5	—	—	—	+42.0	—2.7	+44.5	+32.8
5. Bengal	46.7	608	933	4,327	5,399	57	181	31	54	+30.9	+2.7	+7.9	+7.8	+7.6	+6.4	—.9	+5.1	+6.6	+13.6
6. Bihar & Orissa	34.0	409	1,028	8,284	1,085	—	553	76	2	+28.4	—1.4	+3.8	+1.1	+6.1	+17.0	—.7	+.6	— 32.2	+11.9
7. Bombay	19.3	157	901	7,658	1,974	1	64	137	166	+18.6	—1.8	+6.0	—1.7	+14.5	+1.2	—.7	—5.1	—30.0	+13.6
Aden	.06	706	472	653	7,974	13	—	407	953	+192.9	+22.4	+5.0	—.2	+26.4	+80.7	+80.6	+21.7	+1,360.0	—15.4
8. Burma	13.2	57	955	368	380	8,506	534	195	17	+380.9	+9.1	+15.5	+35.9	+106.6	+36.0	+24.3	+19.0	—27.6	+22.4
9. Central Provinces and Berar	13.9	139	1,001	8,354	405	—	1,160	30	51	+39.8	—	+16.2	—8.3	+9.3	+20.0	+1.1	—.2	— 30.5	+19.4
10. Coorg	.2	104	831	7,733	795	1	1,265	194	12	—2.7	—6.4	—3.1	+4.4	—2.9	+5.9	—8.8	—.9	—	—10.4
11. Delhi	.5	823	733	6,668	2,904	—	—	273	155	*	+18.1	+2.0	+8.8	+6.4	*	*	*	*	*
12. Madras	42.3	297	1,028	8,864	671	—	137	322	6	+35.5	+2.2	+8.3	+7.3	+15.6	—1.2	+1.9	+3.7	—28.6	+14.3
13. N.-West Frontier Province (Districts & Administered Territories)	2.3	168	831	666	9,162	—	—	47	125	*	+2.5	+7.6	+9.9	+17.9	*	+25.0	+1.1	—7.6	+61.1
14. Punjab	20.7	207	830	3,181	5,533	1	—	159	1,126	§+32.9	+5.7	—1.8	+6.9	+10.1	+7.0	§+1.6	§+5.	§+9.7	§+72.8
15. United Provinces of Agra and Oudh	45.4	426	908	8,509	1,428	—	—	44	19	+8.9	—3.1	—1.1	+1.7	+6.2	+5.1	—4.3	—2.7	—6.1	+12.8
States and Agencies ..	71.9	101	938	7,748	1,343	12	415	249	233	+237.7	+1.0	+12.9	—5.0	+20.0	+160.0	—.8	+.7	+3.5	+24.7
16. Assam State (Manipur) ..	.4	45	1,041	5,994	455	9	3,433	106	3	—	+10.9	+21.7	—	—	—	+14.3	+20.6	+200.0	+2,968.2
17. Baluchistan States ..	.4	5	840	334	9,663	—	—	—	3	—	—9.8	—1.9	—	—	—	+7.0	—9.6	—96.9	—72.7
18. Baroda State	2.1	262	932	8,196	763	—	767	35	239	+6.5	+4.6	+4.1	—19.2	+10.7	+9.2	+2.7	+.9	—22.2	+3.0
19. Bengal States	.9	165	880	6,753	3,070	113	36	22	6	+58.0	+9.0	+11.1	+3.3	+2.6	+23.0	+6.7	+11.2	+325.0	+771.9
20. Bihar and Orissa States ..	3.9	138	1,035	8,684	41	3	1,154	117	1	+129.7	+.4	+19.0	+9.5	+25.6	+39.8	+1.5	—2.9	+62.7	+20.3
21. Bombay States	7.4	117	965	8,390	1,135	—	90	19	366	+9.2	+.3	+7.2	—14.4	+16.5	+2.0	+2.7	—4.2	—33.9	+14.0
22. Central India (Agency) ..	6.0	116	954	8,689	553	—	666	15	77	—	—2.2	+12.8	†—16.2	†+9.4	—	†—3.0	†—.5	†+7.5	†+14.5
23. Central Provinces States ..	2.1	66	1,008	7,308	89	—	2,419	176	8	+122.7	—2.4	+29.8	—4.8	+23.4	+49.5	+15.2	—8.3	+11.8	—6.3
24. Gwalior State	3.2	121	883	8,808	555	—	507	5	125	—	—1.3	+5.3	‡	‡	—	‡	‡	‡	‡
25. Hyderabad State	12.5	151	966	8,545	1,041	—	346	50	18	—	—6.8	+20.0	—3.4	+17.2	—	—8.3	—6.0	—41.9	+15.4
26. Kashmir State	3.3	39	890	2,086	7,675	113	—	5	121	—	+5.1	+8.7	+14.2	—	—	—2.9	+6.3	+20.1	+67.6
27. Madras States (including Cochin and Travancore	5.5	510	989	6,642	667	—	24	2,664	3	+66.0	+13.5	+14.9	+13.2	+10.6	+1.7	+9.2	+15.7	—	+26.0
28. Mysore State	6.0	203	962	9,169	570	2	105	119	35	+18.3	+3.0	+4.8	+12.1	+18.1	—17.2	+2.6	+8.3	—54.3	+19.3
29. N.-W.F.P. (Agencies and Tribal Areas)	2.8	111	861	4,563	3,917	21	—	607	892	—	+74.2	+1,831.9	—	—	—	+825.3	+122.1	+336.1	+2,385.7
30. Punjab States	4.4	119	820	5,028	3,100	6	—	9	1,857	—	+4.8	—4.8	+3.8	+10.4	—	+5.9	+3.7	+2.9	+136.4
31. Rajputana (Agency) ..	9.8	76	899	8,299	915	—	488	5	203	—	—6.5	+6.9	—19.0	+22.5	—	—6.7	—8.8	—2.8	+15.4
32. Sikkim State	.1	29	970	6,673	3	3,278	—	45	1	—	—7.1	+49.0	+93.8	—	—	—7.1	—54.5	—	+29.8
33. U.P. States	1.1	191	953	7,827	2,149	—	—	22	2	+18.5	—4.6	+2.3	—1.4	+7.3	+14.8	+52.2	—1.0	+2 .1	+41.7

† Includes Gwalior. § Includes Delhi figures. ‡ Shown against Central India. * Included in Punjab.

TABLE B.

Province.	Census variation per cent. 1901-1911.	Average yearly excess of births over deaths per mille, 1911-1917.	Average yearly excess of deaths over births per mille, 1918-1920.	Census variation per cent. 1911-1921.	Average yearly death rate per mille due to plague and cholera. 1911-1920.
Assam	14.9	5.4	—9.4	13.3	2.5
Bengal..	7.9	4.8	—5.5	2.7	1.9
Bihar and Orissa	3.8	9.1	—9.1	—1.4	3.8
Bombay	6.0	4.7	—19.8	—1.8	3.9
Burma..	15.5	8.5	—.1	9.1	1.2
Central Provinces and Berar	16.2	11.8	—23.1	—	2.6
Madras	8.3	8.5	—3.1	2.2	1.8
North-West Frontier Province	7.6	8.3	—11.1	2.5	.6
Punjab	—1.8	12.5	—5.0	5.7	3.5
United Provinces	—1.1	10.6	—17.8	—3.1	3.6

TABLE C.

PROGRESS OF LITERACY SINCE 1901.

Province, State or Agency.	Number of Literate per mille.					
	All ages, 10 and over.					
	Males.			Females.		
	1921	1911	1901	1921	1911	1901
1	2	3	4	5	6	7
INDIA	161	140	129	23	13	9
Provinces	167	147	134	22	14	9
Ajmer-Merwara	210	163	142	28	17	10
Assam	144	117	89	15	8	6
Bengal	210	187 }	138	23	15 }	7
Bihar and Orissa	114	104 }		7	5 }	
Bombay, including Aden	181	158	148	30	17	11
Burma..	576	496	498	123	79	57
Central Provinces and Berar ..	103	87	79	10	4	3
Coorg	238	194	159	64	36	20
*Madras	199	183	160	26	17	12
N.-W.F. Province	95	81	88	12	8	[illegible]
Punjab (including Delhi)	90	84	86	11	8	4
United Provinces	85	78	75	8	6	3
States and Agencies	127	107	100	29	12	8
Baroda State	277	229	199	52	25	9
Central India Agency (including Gwalior State)	76	64	68	7	3	4
Cochin State	365	329	302	127	79	59
Hyderabad State	65	67	70	9	5	4
Kashmir State	54	53	52	3	2	1
Mysore State	163	142	—	24	15	—
Rajputana Agency	81	79	75	5	3	2
Sikkim State	101	108	125	4	4	3
Travancore State	425	329	283	178	64	39

* Excluding Cochin and Travancore.

TABLE D.

LITERACY BY SEX AND RELIGION.

Religion.	Number per mille who are Literate.								
	All ages, 5 and over.								
	1921			1911			1901		
	Persons	Males	Females	Persons	Males	Females	Persons	Males	Females
1	2	3	4	5	6	7	8	9	10
All Religions	82	139	21	69	122	12	61	112	8
Hindu	75	130	16	64	116	9	57	107	5
Sikh	68	106	16	77	121	16	66	110	8
Musalman	54	94	9	44	80	5	38	70	4
Christian	285	355	210	253	339	159	245	335	147

number of female scholars in colleges and schools has risen by over 50 per cent. between 1911 and 1919 against a rise of 21 per cent. of males. All the main religious communities have shared in the progress in literacy except the Sikhs. Until the Punjab report is rather more advanced the reason for this exception cannot be definitely given. It is probably due to the fact that the remarkable increase in the numbers of the Sikh community during the decade includes a considerable proportion of recruits from the more illiterate classes of Hindus. The progress made in literacy by the Mohammedans is noticeable.

17. I may perhaps add some brief information as to the cost of the census in India. The bulk of the cost, which in the case of so large a population is naturally of considerable importance, falls on the Imperial Exchequer, though some of the local charges are met in part by the Municipalities and other local bodies. The cost in 1911 in British India worked out to between Rs. 5 and 6 per 1,000 of the population, which was somewhat less than in 1901. In the last decade every item connected with the census has substantially increased in price, including the wages of establishment and the cost of paper and printing. The cost on the present occasion will probably be near Rs.12 per 1,000 and varies considerably in different provinces, being over Rs.25 in Burma and under Rs.8 in Bengal and Bihar and Orissa. The expenditure compares well with that in some of the States, *e.g.*, in Baroda Rs.53 and Cochin Rs.24/1 per 1,000. The cost of the census of England and Wales in 1911 is recorded as working out to £5 8s. 8d., which is equivalent to between 81 and 82 rupees of Indian money.

DISCUSSION.

THE CHAIRMAN (Sir Edward A. Gait) said the first thing in Mr. Marten's most interesting paper which would impress all those who had had experience of census work in India was the extent to which that work was hampered by the non-co-operation movement, which was in full swing at the time. Not only did that movement greatly impede the actual taking of the census, but also, by arousing a spirit of insubordination, it made it extremely difficult to control the large temporary establishments that were employed in working out the results. Very great credit was due to all concerned for the way in which they surmounted their difficulties, and it was gratifying to learn that in spite of them the census of 1921 was as accurate as any of its predecessors so far as the total number of persons was concerned, even though in some parts the detailed entries in the schedules might have been filled in with less care than heretofore. There had been little or no change in the nature of the information collected, but it was said that in dealing with it more attention would be paid to the industrial aspects of the statistics and less to religion, caste and language. That was as it should be. The latter subjects had already been very fully explored, and it was not to be expected that much fresh information could be obtained by means of the census. On the other hand, India was developing very rapidly on the industrial side, and it was most desirable that the fullest possible use should be made of the census to throw light on the movements in progress. For that reason it was satisfactory to find that the special Industrial Schedule introduced in 1911 had been used again. That schedule provided a great deal of useful information regarding industries of all kinds not obtainable from the ordinary personal schedule, and a comparison of the information now obtained with that obtained ten years previously would afford a valuable guide to the advance made during the decade. When the paper was written the tabulation of the more complicated statistics had not been completed and the figures at the end of the paper gave only a few of the main results. The outstanding fact brought to notice was that during the last ten years the population of India had grown by only four millions or very little more than 1 per cent. That was the smallest increase recorded since the first general census taken half a century ago. The author told them that that was entirely due to the influenza epidemic which swept over the whole world soon after the close of the Great War and in India alone carried off 12½ million persons. His own experience in Bihar and in Orissa fully confirmed what the author had said of that fearful visitation. Whole families and even villages were laid low at the same time and there was no one left to tend the sick or to look after their food. An Indian friend of his, who soon afterwards visited a remote village in Chota Nagpur in order to enquire into the customs of the primitive inhabitants, found that with the exception of two old women, the whole population had been swept away. There was no doubt that it was in the more remote and backward tracts that the influenza epidemic caused the greatest mortality. The increase of nearly 23 per cent. in the number of persons returned as Christians was an indication of the effect of missionary propaganda. That increase, great as it was, was smaller than that recorded at the two previous censuses. One obvious reason was that during the war missionaries of enemy nationality were interned and eventually deported, and that, no doubt, had reduced the efficiency of the missions to which they belonged.

A further explanation was given in a recent issue of "The East and the West," where it was stated that whereas on previous occasions the number of persons returned as Christians at the census exceeded the number claimed by the local missions, on the present occasion the reverse was the case, and the writer was of opinion that, owing to political ferments, the census staff were less willing than formerly to enter persons as Christians. It was interesting to learn that the proportion of females to males, according to the census of 1921, was lower than on any previous occasion. That seemed to confirm the view expressed in the census reports for 1901 and 1911 that the deficiency of females was in the main genuine, being due to social customs and conditions prevailing amongst large sections of the population which were adverse to female life. Of those the most important were the neglect of female infants, the marriage of immature girls and unskilful midwifery. If the deficiency were due to omissions from the record, owing to the reticence of Indians regarding their womenfolk, then the difference, instead of growing, would tend to disappear. The author had not discussed in his paper the subject of infirmities, but had sent him an advance copy of the main infirmity table, and it might be of interest to mention one important fact which it disclosed. Whereas the return showed an increase in the aggregate number of persons afflicted by one or other of the four infirmities dealt with at the census—insanity, deaf-mutism, blindness and leprosy—there was a smaller number of lepers than on the last occasion. The proportion of lepers per 100,000 of the population was now only 32 against 57 in 1881. It was admitted that lepers of good social position endeavoured to conceal their affliction, but that must generally be known already to the enumerators, who were mostly local men. Moreover, the vast majority of lepers were poor persons, usually beggars, who lived by parading their sufferings, and with them there was no question of concealment. In any case, the omissions from this record were assuredly not more numerous than they were in 1881, and it might safely be concluded that leprosy was gradually disappearing. That might be due to various reasons, partly to the segregation of lepers in asylums, most of which were maintained under the Mission for Lepers, partly to legislation, and partly, perhaps, to the improved condition of the poorer classes. In that, as in many other respects, it was necessary to wait for the final report of the Census Commissioner before coming to any definite conclusions. The paper, interesting as it was, had merely whetted his appetite, and he was sure everyone would look forward to the publication of the final reports of Mr. Marten and his colleagues, the Provincial Superintendents.

Sir J. Athelstane Baines, C.S.I., thought the paper was a remarkably good one, as it showed that a census was a human process and not a mere mehanical absorbing of schedules and turning out of tables. The human side was emphasised perhaps more in the reports on the Indian census than in those of any other. As an old census taker he could appreciate the work that had been done, because he knew the difficulties under which his successors laboured, and the anxieties which beset them right up to the time of taking the census. His first work in the census field was done in 1872, and he had followed every census with more or less care, and believed that every successive one had been better than that which preceded it. The pioneers devised the foundations, and the use made of them had been improved, either in method, machinery or statistical handling on every occasion since. The difficulty in obtaining volunteers for anything in the nature of public service was not confined to India, and he had no doubt that that difficulty would increase rather than diminish. On account of the expense, the census on the next occasion might have to be taken of the *de jure* instead of as at present the actual. He thought the present method in India was very accurate, and a more accurate count of the people was obtained by it than had been obtained in any other large country. Amongst statisticians a good many held that the *de jure* population was more useful than the *de facto*. In countries where the people were always on the move that might be so, but in India, where migration was a very unimportant characteristic, it was not. The Indian census report had always been distinguished by its attention to ethnography, the distribution of religions and castes, and from what he had heard those contributions to ethnological science had been of the greatest possible help to those who were interested in that branch of study, and were highly appreciated throughout the whole civilised world. General reports should now give place to more intense study, or regional studies by special enquirers. The development of industry in India had been so extraordinarily rapid of late years that the census had to give it more consideration than had been done in the past. The movement of population was a very important factor in the great question of the relation between population and resources and was one of the most difficult questions the census had to deal with. Like all tropical countries India was prolific, and the social system encouraged a large number of births. This was accompanied by a high death-rate, so that the natural increase was the result of a great waste of young lives.

Sir C. Sankaran Nair, C.I.E., said, from what he knew of the author personally and his work, he thought the report, when it was published, would not fall below the high standard which the Chairman had set as Census Commissioner. Mr. Marten had difficulties to

contend with which did not exist before, due to the political conditions of the country. He (the speaker) well knew some of the difficulties caused by religion and castes. He remembered a caste in Madras complaining that they had been shown in the census as belonging to an inferior caste, while they really belonged to a superior caste, and threatening the Government official and the Government of Madras with an action for defamation; they were with difficulty restrained from taking that course. Some method should be devised by which, in such cases the census reports might give the views of the different parties, instead of what the enumerator thought the facts to be. He did not think Government enumerators or any Government official should insist upon saying that a man belonged to a particular caste, when that man himself did not want to be known to belong to that caste. So far as the Hindus were concerned, there was a strong feeling, due to political considerations, that nobody should be called an Animist, and that he should appear as a Hindu for all purposes. They put forward the view that the plan complained of was adopted because the Government desired to reduce the strength of Hindus. Census operations in India dealt with a number of things which did not really fall within the scope of census operations elsewhere. That had been useful not only to students of anthropology and of social matters, but of great advantage in other respects. With regard to the loss of population due to influenza, the epidemic started in the Bombay Presidency, and went north and south and east and west, and stopped in Bihar and Orissa. In Assam, Bengal and Burma it did not affect the population very much, nor in the extreme south. The result in the Punjab was curious, because, although they had influenza there, the population went up by five per cent. It would be interesting to learn from the report whether the Government were considering remedial measures, and were going to take steps to deal with any similar outbreak in the future. It had been his intention, if he had remained in India, to request Mr. Montagu to see whether the subject of the duration of life could not be dealt with in census reports. He did not think any previous reports showed the average duration of life of an individual. He quite realised that the return could not be quite relied upon, but it would be interesting to know whether, according to the statistical returns, the duration of life was now higher or lower than that which could be made out from the returns of 1911 or 1901. A return was made on one occasion which had not been published, but the result was not very satisfactory.

Mr. Harold Cox said that while writing a book on population he came across Sir Edward Gait's report on the Indian census, and it was a great pleasure to him to find the valuable information he set out in that report. It would be of value if Sir Edward could see his way to condense the report into a comfortably sized book which the general population could buy and read. He should like to impress upon the author of the paper the danger of percentages. He noticed that towards the end of the paper Mr. Marten said that the women students had increased by 50 per cent., and the men students by only 21 per cent. That meant nothing, because, supposing there had been two women students and one more had been added, that would have been 50 per cent. increase, but there might have been a thousand male students who had increased to 1,210. This arithmetical confusion was very much in evidence in the daily papers when they commented on the birth-rate. When they said that the birth-rate had declined, they said there was national decay. But the decline of the birth-rate meant nothing unless it was known over what population the birth-rate was taken. If there was only a population of one million, with a very high birth-rate, only a small increase was obtained, but if there was a population of forty million, a low birth-rate would give a very large increase. He had been particularly pleased with the care the author had taken to point out the difficulty of getting accurate statistics. His own impression was that no statistics were accurate; they had to be looked upon as approximations to the truth.

Mr. L. Middleton, replying to Sir Sankaran Nair on the question of the expectation of life, said the tables prepared gave very detailed statistics of the age of people and the number of people living at each age, and there were statistics for every province and for each of the main divisions of the population. These were sent to the Actuary to the Government of India, who prepared tables showing the expectation of life at every age based on the census statistics, and checked those that had been accepted in the previous census by the light of the new census, and modified them accordingly. Those publications were available.

Sir Henry Sharp, C.S.I., C.I.E., in proposing a vote of thanks to Mr. Marten for his excellent paper, and to Mr. Middleton for reading it, said he could speak with considerable sympathy and a good deal of feeling with regard to the difficulties which the author had had to encounter during the census, for in a humble way he had collaborated with him and given him as much assistance as possible. The question of the age periods was most carefully discussed, in connexion with the present census, between Mr. Marten and himself and he hoped good data would be available for the Actuary when the actuarial work came along. He should like to say, for the comfort of any future Census Commissioner or Superintendent, that the difficulties which Mr. Marten had described were very extraordinary, and he hoped very exceptional.

The position in the provinces had deteriorated just at the time the enumeration took place, but since then there had been some improvement.

COLONEL SIR CHARLES YATE, Bt., C.S.I., C.M.G., M.P., seconded the motion, in which he included the thanks of the meeting to Sir Edward Gait for presiding. He said that Sir Henry Sharp hoped that the deterioration in administration in India had stopped, but he honestly confessed, from what he could judge by the telegrams from India, that he had not seen any signs of that yet. The special difficulties described by Mr. Marten in paragraph 4 of his paper, in the form of direct obstruction and refusal to co-operate in the work, was sad reading, and showed what a different spirit animated the people from what it had been in his day. He was proud to speak in the presence of an old Indian (Sir Athelstane Baines), who, like himself, went to India more than 50 years ago—he himself arrived there in February, 1868. The author had put the question as to whether India could support a considerable increase of population in the future under any conditions that seemed likely to arise, and that was very important. It was a new thing that India should have to import wheat, and it showed the great advantage of the imperial connexion that India had with Australia and the rest of the empire. With regard to leprosy, he asked a question in the House of Commons not long ago on the subject, and received a detailed reply. It had been said that new life had been gained by lepers in India owing to the scientific treatment now given in the Leper Asylums, and he hoped that would have a great effect in decreasing the number of lepers in India. There were a number of cases of leprosy in England, and he had asked the Ministry of Health whether it would not be possible to make leprosy a notifiable disease.

The vote of thanks was carried unanimously and the meeting terminated.

OBITUARY.

THE HON. SIR JOHN PRINGLE, K.C.M.G., M.D.—Sir John Pringle died recently at Kingstown, Jamaica. Born in 1848 he studied at the University of Aberdeen, whence he graduated M.B., C.M. in 1872. He settled in Jamaica: here he became one of the largest landowners, was Custos of St. Mary, a member of the Governor's Council, and a nominated member of the Legislative Council.

He was elected a Member of the Royal Society of Arts in 1898.

NOTES ON BOOKS.

THE PENITENT. By Edna Worthley Underwood. Boston and New York: Houghton Mifflin Company.

The present volume is the first of a trilogy which Mrs. Underwood is writing to picture the crumbling of the great Russian civilisation. It deals with that unhappy country under the sway of Alexander I. It has two heroes, Alexander and the poet Pushkin. In the first part we have a striking and life-like account of an almost inconceivably gorgeous, corrupt and immoral court; in the second part, when Pushkin, implicated in a revolutionary plot, is banished to the South of Russia, we have a wonderfully graphic picture of life as it was a century ago in the Ukraine, the Crimea, and the Caucasus. The story of the exile's journey from the snows of the North, through the endless plains, to his ultimate destination, is exceedingly vivid, and leaves one with an overwhelming impression of the vastness of Russia and its potentialities for good or evil.

The Czar is "The Penitent." He is represented as being of a mild and merciful disposition, intent, among other things, on the gradual abolition of serfdom, and encouraging the arts and commerce of his country. His conscience was troubled, however, for his share in the murder of his father, and his good intentions were thwarted by Metternich and others who believed that the only hope for Russia was the maintenance of an autocratic despotism. Mrs. Underwood draws him with a sympathetic touch, and he is indeed a tragic figure, torn between his anxiety to realise his finer ideals and to keep the peace with his crafty advisers. We do not know, however, what authority the author has for her account of his end. The usual story is that he died at Taganrog, whither he had gone on a tour of inspection of his southern provinces, in 1825. According to this account he vanished from the court, joined a band of pilgrim monks, became known as Kusmitch the Saint, and spent his days in healing the sick and comforting the afflicted.

Mrs. Underwood has chosen a great subject for her theme; she writes of it with full information, sympathy and literary skill; and the other two volumes of the trilogy, which, we understand, will bring the story up to the present day, will be awaited with much interest.

COLOUR SENSE TRAINING AND COLOUR USING. By E. J. Taylor. London: Blackie & Son, Ltd. 2s. 6d. net.

This handbook for teachers was originally published in 1908, and the present issue appears to be a reprint of this without any alterations or additions. It is the outcome of a course of lessons, delivered by the author, arranged as

a progressive series for elementary day classes and evening students.

There is much sound information on the principles of colour in this little primer, the main objective being cultivation of the sense of colour. The author devotes rather an unnecessary amount of space to rival theories as to the so-called Primary Colours. He seems to regard "the red-yellow-blue theory" much as a Puritan of old regarded incense and graven images. It surely was never more than a working hypothesis which has long been superseded or developed into more accurate conceptions as our knowledge of light and colour has been extended by the researches of physicists.

The book is illustrated by many coloured diagrams, but the rendering of the colours is very inaccurate, which detracts from their usefulness. Pure "primary" red is represented throughout by the broken brownish red one associates with oxide of iron. It is a pity that in this reprint the publishers have not taken advantage of the extremely accurate methods of printing which have become a feature of modern illustration, owing to a knowledge of the principles outlined by the author.

N.H.

GENERAL NOTE.

Benares Brasswork.—According to the Principal of the Lucknow School of Arts and Crafts, a considerable change has occurred in the Benares metalwork industry, the large export of decorative articles having caused the sacrifice of workmanship, design and shape to cheapness. Another reason given for the deterioration is the custom of selling Benares brasswork by weight. He recommends that a school of instruction be established close to the "brass bazaar" and that sales by weight be abandoned. It appears that there are some 225 families of metalworkers in Benares and that a good man may earn up to Rs. 100 a month.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

Monday, April 9 .. Royal Institution, Albemarle Street, W., 5 p.m. General Meeting.
Geographical Society, 135, New Bond Street, W., 8.30 p.m. Mr. P. Bigelow, "Geographical Influences bearing upon Japan and her Neighbours."
British Architects, Royal Institute of, 9, Conduit Street, W., 8 p.m. Mr. H. M. Fletcher, "The Architecture of Provincial France."
Surveyors' Institution, 12, Great George Street, S.W., 8 p.m.
Transport, Institute of, at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C. (Metropolitan Graduate and Student Society), 5 p.m. Mr. E. W. Bayliss, "Tramways—Their Scope and Object—Place in a Comprehensive Scheme of Transport and in Municipal Enterprise."
Engineers, Cleveland Institute of, Technical Institute, Corporation Road, Middlesborough, 6.30 p.m.
Rubber Industry, Institution of, Engineers' Club, 39, Coventry Street W., 8 p.m. Dr. D. V. Twiss "Rubber Pigments."
Chemical Industry, Society of, at the Engineers' Club, 39, Coventry Street, W., 8 p.m. 1. Messrs. S. S. Zilva and J. C. Drummond, "The Cod Liver Oil Industry of Newfoundland." 2. Messrs. E. W. Blair, T. C. Wheeler and J. Reilly, "A Study of the "Separation of the Gases formed in the N - Butyl - Alcohol - Acetone Fermentation Process."

Tuesday, April 10 .. Petroleum Technologists, Institution of, at the Royal Society of Arts, John Street, Adelphi, W.C., 5.30 p.m. Mr. A. E. Chambers, "Potrers No. 4.—The History of One of Mexico's Earliest and Largest Wells."
Civil Engineers, Institution of, Great George Street, S. W., 6 p.m.
Metals, Institute of (Local Section), Chamber of Commerce, New Street, Birmingham, 7 p.m. Annual General Meeting.
Photographic Society, 35, Russell Square, W.C., 7 p.m. Mr. H. M. Cartwright "A Study of Bichromated Gelatine, with reference to Photogravure."
Colonial Institute, Hotel Victoria, Northumberland Avenue, S.W., 8.30 p.m.
Alpine Club, 23, Savile Row, W., 8.30 p.m. Mr. P. C. Visser, "The Karakoram Himalayas."
Royal Institution, Albemarle Street, W., 3 p.m. Sir Arthur Keith, "The Machinery of Human Evolution." (Lecture I.)
Chemical Industry, Society of (Local Section), The University, Edmund Street, Birmingham, 7 p.m. 1. Mr. F. R. O'Shaughnessy, "Some Observations on the activated Sludge Process." 2. Mr. E. J. Lush, "Some Studies in Catalytic Hydrogenation."

Wednesday, April 11 .. Literature, Royal Society of, 2, Bloomsbury Square, 5.15 p.m. Professorial Lecture.
Electrical Engineers, Institution of (Wireless Section), Savoy Place, Victoria Embankment, W.C., 6 p.m. Dr. N. W. McLachlan, "Magnetic Drum High Speed Recorder and Key Transmitter."

Thursday, April 12 .. Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.
Metals, Institute of, at the Institute of Marine Engineers, 85, The Minories, E., 8 p.m. 1. Annual General Meeting. 2. Dr. S. W. Smith, "The Surface Tension of Metals."
Optical Society, at the Imperial College of Science, South Kensington, S.W., 7.30 p.m.
Royal Institution, Albemarle Street, W., 3 p.m., Prof. A. O. Rankine, "The Transmission of Speech by Light." (Lecture I.)
British Decorators, Institute of, Painters' Hall, Little Trinity Lane, E.C., 3 p.m. Annual General Meeting.
Central Asian Society, at the Royal United Service Institution, Whitehall, S.W., 5 p.m. Captain D. Norris, "The British Navy in the Caspian—1918-19."
Camera Club, 17, John Street, Adelphi, W.C., 8.15 p.m. Mr. E. A. Rubias, "The Edible Crab."
Electrical Engineers', Institution of, Savoy Place, Victoria Embankment, W.C., 6 p.m. Mr. A. W. Warren, "The X-Ray Examination of Materials."

Friday, April 13 .. London Society, at the Royal Society of Arts, John Street, Adelphi, W.C., 5 p.m. Mr. C. H. Bressey, "London's New Trunk Roads in the Making."
Japan Society, 20, Hanover Square, W., 5 p.m. Paper by Professor Hishinuma.
Royal Institution, Albemarle Street, W., 9 p.m. Dr. W. H. Eccles, "Studies from a Wireless Laboratory."
Astronomical Society, Burlington House, Piccadilly, W., 5 p.m.
Malacological Society, at the Linnean Society, Burlington House, W., 8 p.m.
Photographic Society, 35, Russell Square, W.C., 8 p.m. Mr. J. R. H. Weaver, "Cathedrals of Northern Spain."
Chemical Industry, Society of (Local Section), The University, Liverpool, 6 p.m. Meeting of the Chemical Engineering Group."

Saturday, April 14 .. Royal Institution, Albemarle Street, W., 3 p.m. Sir Owen Seaman, "Sonnets and Ballads of Dante Rossetti." (Lecture I.)

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FRIDAY, APRIL 13, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICES.

NEXT WEEK.

MONDAY, APRIL 16TH, at 8 p.m. (Cantor Lecture.) E. KILBURN SCOTT, Assoc.M.Inst.C.E., M.I.E.E., "Nitrates from Air." (Lecture II.)

WEDNESDAY, APRIL 18th, at 4.30 p.m. (Ordinary Meeting.) HAL WILLIAMS, M.I.Mech.E., M.I.E.E., M.I.Struct.E., "Modern Abattoir Practice and Methods of Slaughtering." W. PHENÉ NEAL, Alderman of the City of London, late Chairman of the Cattle Markets Committee of the Corporation, will preside.

FRIDAY, APRIL 20th, at 4.30 p.m. (Joint Meeting of Dominions and Colonies and Indian Sections). SIR RICHARD A. S. REDMAYNE, K.C.B., M.Sc., M.Inst.C.E., F.G.S., "A Review of the Base Metal Industry, with Special Reference to the Resources of the British Empire." The RT. HON. LORD EMMOTT, G.C.M.G., G.B.E., will preside.

CANTOR LECTURE.

On MONDAY EVENING, APRIL 16th, Mr. E. KILBURN SCOTT, Assoc.M.Inst.C.E., M.I.E.E., delivered the first lecture of his course on "Nitrates from Air."

The lectures will be published in the *Journal* during the Summer recess.

PROCEEDINGS OF THE SOCIETY.

TWELFTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 21ST, 1923.

SIR RICHARD MUIR (Senior Counsel to the Treasury, Central Criminal Court) in the Chair.

THE CHAIRMAN, in introducing the lecturer, said it was in 1907 that Mr. Mitchell first began to follow the paths of crime, and he (the Chairman) had been the fortunate person who had introduced him into that method of adding to his already large emoluments as a scientist. Since then he had on many occasions profited by the assistance of Mr. Mitchell in important and difficult cases in which the question of handwriting as evidence was the prominent point. He knew that the audience would receive information from Mr. Mitchell that evening which would show that the question of handwriting as evidence had not stood still since 1907 and that important advances had been made in the scientific methods of determining the person whose hand had written any particular document which might be the subject of enquiry.

The following paper was read :—

HANDWRITING AND ITS VALUE AS EVIDENCE.

By C. AINSWORTH MITCHELL, M.A. (Oxon.), F.I.C.

Until a comparatively recent date the examination of handwriting has been regarded in the scientific world with considerable suspicion, and, as Mr. A. Lucas has well observed, it has been bound up with such subjects as phrenology, graphology and palmistry in the bundle of things scientifically damned.

The main reasons for the cloud under which it has lain are, firstly, that many of the so-called experts of the past had not been trained in scientific methods, and so ventured to express their opinions in a dogmatic form which no observed facts could have justified ; and, secondly, that, after making such positive assertions, they were not infrequently shown to be wrong and so brought discredit both upon themselves and upon the methods which they had employed.

For example, a leading handwriting specialist of the past generation claimed in the witness box that his methods gave infallible results and that his son, whom he had trained, was also infallible. He was compelled to admit, however, that on one occasion he and his son had appeared on opposite sides, and this admission effectually disposed of his claim to infallibility and

incidentally of the case in which he was then appearing.

There is, perhaps, some excuse for the *ex-cathedra* attitude which was assumed by some of these men, for judges were inclined to attach undue importance to the opinion of the specialist, apart from the facts upon which it was based, and so helped to foster his belief in the idea that he had some mysterious power which did not come within the scope of the uninitiated. Even at the present day, this veneration for the opinion of the specialist is not quite extinct, for I have, myself, seen a judge of the High Court reject the evidence of a man with regard to his own alleged signature, on the ground that the witness was not an expert in handwriting, and this notwithstanding the fact that the man pointed out in detail in what respects the alleged signature differed from his genuine writing. It may be added that the judgment in this case was reversed on appeal.

It is interesting to follow the developments of the use of specialised evidence in handwriting in our Courts. Prior to 1854, such outside evidence was quite inadmissible, except in the case of ancient documents or when writing having a bearing upon the case was already before the Court.

The law on the subject, as laid down by Blackstone in the following passage (*Laws of England*, IV., c. 27, p. 358), was closely followed : "Secondly, though from reversal of Colonel Sidney's attainder by Act of Parliament in 1689 (*State Trials*, 472) it may be collected that the mere similitude of handwriting in two papers shown to a jury without other current testimony, is no evidence that both were written by the same person : yet undoubtedly the testimony of witnesses well acquainted with the party's hand, that they believe the paper in question to have been written by him is evidence to be left to a jury."

The idea underlying this distinction was evidently a belief that those who are constantly seeing the handwriting of a particular person become so familiar with what is vaguely termed its "general character," that they are in a position to recognise it at a glance, just as they might recognise the person by his facial characteristics or individual traits.

An interesting historical example of the inconclusiveness of such evidence is afforded by the trial of Spencer Cowper (the grandfather of the poet) at the Hertford Assizes in 1669 on the charge of murdering a young woman named Sarah Stout. Letters alleged to be hers had been put forward as evidence that she had committed suicide and the writing in these letters had been identified by two witnesses who were familiar with her handwriting. On the other hand, her mother and her brother gave evidence that they did not believe the letters to have been written by her, and the judge in his summing up left the question to the decision of the jury. The defendant was acquitted, but mainly as a result of evidence on other points.

Attempts were made in the early part of last century to extend the scope of evidence by producing engravers and examiners of franked letters as witnesses of the genuineness of handwriting with which they had been previously unacquainted, but such evidence was so consistently refused that Lord Denman expressed the opinion that that chapter might be considered as expunged from the book of evidence.

In 1836 the question of the admissibility of evidence on handwriting by a bank inspector was made the subject of an appeal, with the result that judges were equally divided in opinion. Even when, eighteen years later, specialised evidence as to handwriting was made permissible by statute, it was only allowed in civil actions, and it was not until 1865 that it was also made admissible in criminal trials.

At the present day both kinds of evidence—that of the specialist and that of the intimate acquaintance—are used as proof of handwriting, but the latter must usually be regarded as much more fallacious than the former.

If we take, for example, a forged signature, it will generally show a more or less close general resemblance to its model ; otherwise, forged signatures would not so frequently be passed as genuine by bank cashiers, the class of men most frequently called as witnesses to identify handwriting by recognition at sight. At the same time a forged signature may frequently show less obvious characteristics which would escape the notice of an untrained eye, but which would distinguish it from the genuine signature.

The absolute untrustworthiness of the general impression of the genuineness of handwriting formed by relatives or friends is illustrated by two curious cases early in 1915.

The first of these was an action arising out of the disappearance of the *S.S.* "*Oriole.*" That vessel had left London on January 29th for Havre, and was last seen off Dungeness the next day. In March a Guernsey fisherman found a beer bottle floating in the sea, and this contained an envelope upon which were the words: "Oriole torpedo sinking." The writing of these words closely resembled that of one member of the crew, but, on the other hand, was positively identified by the widow of the carpenter as the writing of her husband. The judge decided in favour of the Insurance Company, holding that the vessel had been sunk by an act of war. He expressed the view that the message in the bottle was a genuine one, without attempting, however, to decide to which member of the crew the writing was to be attributed.

The second case shows in a still more striking manner the risk of basing a judgment concerning handwriting on the evidence of relatives unless their opinion is supported by a demonstration of facts.

This case of *Macbeth v. King*, was an action between two firms of underwriters to decide which of the two was liable for the loss of the *S.S.* "*Membland,*" which had presumably been lost at sea early in 1915. Two months later the stave of a wooden bucket was picked up on the beach near Hornsea, and on this was written in indelible pencil the words "Membland torpedoed engine room port side. Goodbye dear." If this were genuine, it would prove that the vessel had fallen a victim to war risks; otherwise it was contended that the vessel had been lost through ordinary marine risks.

At the Board of Trade enquiry in 1915, the writing on the stave was identified by the relatives of no fewer than six different members of the crew as that of their respective husband or son, as the case might be, whereas the mother of the man who had in all probability written the words stated that it was not the writing of her son. She had failed to make allowance for the fact that the words were written in pencil on a hard wooden surface.

In giving his decision in the subsequent action in 1916, the judge held that the stave might be genuine, but that he was not convinced on the point. He decided on other grounds, however, that the vessel had been lost by war risks.

It will be seen from these cases alone, that there is ample justification for the plea put forward by Mr. A. S. Osborn, of New York, that before the evidence of friends or relatives upon handwriting is accepted, the witnesses should be examined to see whether they have sufficient knowledge or intelligence to warrant their testimony being received.

Quite unconsciously the will to believe a particular piece of writing to be genuine must often play a part in its identification. It is only upon such a supposition as this, coupled with what Mr. Osborn terms "form-blindness," comparable with colour-blindness, that we can account for the remarkable fact that in 1795 Ireland was able to palm off on a gullible world his obvious forgeries of documents of Shakespeare and his contemporaries, and on the strength of them to get Sheridan to produce a fabricated play to an over-crowded house at Drury Lane Theatre. Even those who, like Malone, protested from the first that the Ireland documents were forgeries, were for months unable to shake the faith of those who had accepted them as genuine, and it required the confession of Ireland himself finally to discredit his creations. And yet, even a simple comparison of the individual letters with those of genuine documents with a demonstration of their differences in form, would have been sufficient to carry conviction to any unprejudiced mind.

In those days, however, systematic methods of studying handwriting had not been devised, and any criteria for a judgment were derived from the general impression of the writing as a whole and a haphazard comparison of the forms of isolated letters and words.

Much more than this is required for the scientific examination of handwriting, which involves not only a study of the characteristics of normal and abnormal writing and of the influence of various factors, such as pathological conditions, upon it, but also exact measurements of the quantitative relationships between different parts of the writing itself in comparison with those of an admitted standard writing.

Writing, which may be defined as expression of the thoughts by means of visible characters, has probably evolved from a pictorial representation of external objects by way of ideographs or conventional symbols. It is not uncommon to find insane people making use of pictorial

representation in preference to writing, and Lombroso sees in this an atavistic reversion to the original mode of expression.

The form of handwriting is, to a large extent, characteristic of the individual. In some degree, too, it is an inherited trait, liable to vary with emotional changes and modified more or less permanently by certain forms of disease and by external factors such as education and environment. The individuality of handwriting is clearly shown by the results of certain experiments recorded by Preyer (*Psychologie des Schreibens*) who found that the writing produced by men who had learned to hold the pen in the mouth, in the toes, or in the joint of the knee, had the same essential characteristics as their normal handwriting.

If we consider the various factors which contribute to this individuality, we can hardly doubt that heredity plays an important part. Everyone will be familiar with instances where sons have a very similar writing to that of their father or grandfather, and the probability of conscious imitation may be excluded in some of the cases, at all events; for such resemblances occur in the writing of men who have never known their parents. It would be strange, indeed, if some of the characteristics of such a distinctive art as writing were not passed on.

It is worth noting in this connexion that there is sometimes a tendency for sons to write like their fathers and daughters like their mothers, as in the instance shown on the screen.

The question of the writing of twins is an interesting side-issue. In view of the fact that some pairs of twins show pronounced similarities and others pronounced differences in their mannerisms, we should anticipate the occurrence of similar extremes in their handwriting.

It has been shown by Professor Thorndike that the similarity in the handwriting of certain pairs of twins may be seen even in the unformed writing of young children. As a test, seventy-two pairs of twins from seven to fifteen years old, were asked to write certain words on slips of paper, which were then divided into two sets and handed to twelve men and women of average intelligence to be sorted into their correct pairs. Out of the seventy-two possible pairings, fifty-eight were made in all, and in one instance the resemblance was so close that the writings were correctly matched by eleven of the twelve judges. This experiment would probably have been still more striking if it had been applied to the writing of adult twins.

Among the external factors which influence the formation of writing, two of the most important are education and environment, which to some extent overlap. Just as there are certain facial characteristics by which we can often distinguish different nationalities, the members of which still preserve their individuality of appearance, so there are often certain distinctive features which are typical of the writing in different countries at different periods.

There is, for example, a very great difference between typical English and French writing of the 16th century, whereas in the 18th century the average handwriting in the two countries had more in common.

These broad differences in national writing at different periods must be largely attributed to the style of the writing taught to the children in the schools, and to subsequent conscious or unconscious adaptation of the style to the conventional standards of the time.

Examples of this will be familiar to everyone. The old writing masters taught their pupils to write in characters which should resemble as nearly as possible an engraved copper plate; and in the early Victorian period a sloping Italian handwriting was regarded as fashionable and taught in all the schools for girls. Other instances of the kind are to be found in the handwriting taught for special purposes, such as the "Civil Service hand," or the form of writing taught in business training colleges, the examples of which, shown on the screen, were sent to me by the late Mr. W. Kinsley, of New York.

Handwriting thus consciously formed will differ from what may be termed the normal handwriting of a person, which will only assert itself completely when the writing act becomes unconscious, though even then certain habits formed by early training may persist.

Writing may be regarded as normal when the thoughts of the writer are centred upon what is being written, and without a mental side-glance at the form of the writing itself. It may be remarked in this connexion that an artist is particularly prone to make experimental changes in his writing with a view to the decorative effect of words and letters.

Unconscious imitation is another factor which may influence the general form of handwriting, and in extreme cases this may be so pronounced that when a letter is being answered, there is a tendency for its characters to be imitated.

Emotional influences often have some effect upon handwriting, although the alterations thus produced are often only slight and temporary. For example, a man writing in a violent temper will often make more vigorous cross-strokes and dot the "i's" more heavily, whilst another man writing in a depressed state of mind may produce writing which differs from his normal writing habit.

The most interesting historical record of this is to be found in the handwriting of Napoleon at different periods of his career. Very striking, for instance, is the difference between the orderly writing of the signature after his victory at Austerlitz and the blotted scrawl dashed off after his defeat at Leipzig.

Of the many temporary influences which tend to modify handwriting none is more remarkable than the effect of hypnotic suggestion.

It has been shown by Preyer that some persons, when under hypnotic influence, form more regular characters than when in their normal condition, whereas others are made to form childish and badly formed letters.

Professors Lombroso and Richet proved in numerous experiments that a suggested change of personality in a hypnotised subject is accompanied by a corresponding change in the writing.

A striking series of experiments on these lines was made upon a Trieste student who, within an hour, was made to assume successively the characters of a child, a peasant woman, Napoleon, Garibaldi and an old man of 90, and to write words in each of his assumed characters, and the writing not only differed from the normal handwriting, but also suggested some of the characteristics of writing typical of the individual he was temporarily representing. In a private communication shortly before his death, Lombroso informed me that it was quite possible that the hypnotised student was familiar with the handwriting of Garibaldi. The subject is obviously one that would repay further investigation.

In addition to such temporary influences on writing, there are also many of a more pronounced kind caused either by impairment of the central control in the brain, or by alterations of an expressive nature in which there is mechanical inability to make the co-ordinated movements that produce written characters. The best known form of mechanical inability to produce the exact forms desired is to be found in the trembling writing of old age.

More significant disturbances of the writing are to be found in the case of writer's cramp, in which the muscles of the hand and arm contract and cause the writing to be atactic and trembling; and in St. Vitus' dance, which is characterised by sudden and rapid twitchings of the muscles. Extreme instances of atactic writing, which is not always accompanied by pronounced impaired intelligence, are of common occurrence in certain stages of general paralysis. The writer may be quite clear as to what he wishes to say, but is unable to compel the muscles of the hand to make the letters.

In other cases there may be more control over the formation of the letters, but with a tendency to multiply them or repeat them in the wrong place.

In typical agraphia there is either complete inability to write, or else only parts of letters may be formed, or meaningless strokes may be endlessly repeated under the impression that sentences are being formed.

A remarkable case of agraphia came under the notice of Dr. Byrom Bramwell, who kindly gave me his permission to reproduce the graphic result. The patient, who had been paralysed in the right arm, had lost the power of reading words, but not of recognising individual letters. He could draw with the left hand and recognise the different parts of a house he had drawn. In this case some power of expressing ideas by means of drawing had apparently been retained after the capacity of expression by writing had been lost. This is an illustration of the atavistic tendency to revert from writing to drawing to which Lombroso called attention.

Whether the writing centre in the brain is a large diffused area or is small and circumscribed has long been the subject of discussion among brain specialists, and attempts have been made to localise the lesions responsible for the various forms of aphasia, alexia and agraphia in definite anatomical sites, but Dr. H. Head has shown (*Brain*, 1920, 43, 87, 413) that this

is not in accordance with his experience or that of more recent workers. It seems to be accepted, however, that the writing centre is bilateral, and has its seat in both hemispheres of the brain. This would explain why in cases of paralysis of the right hand through injury to the left side of the brain, the left hand is readily trained.

The phenomenon of mirror writing points to the same conclusion of the duality of the writing centre. This backward writing is not uncommon with weak-minded children, and is also a frequent result of the first attempts of perfectly healthy children to write with the left hand. It is also a common phenomenon where paralysis of the right side has occurred.

The examples shown on the screen represent the mirror writing of a child of 14, who wrote in this way with the left hand, and of a working woman of 65, who, after paralysis of the right arm, wrote in this way with the left hand.

The most interesting historical instance of the kind is to be found in a manuscript of Leonardo da Vinci at Milan, and we have contemporary authority for the knowledge that the artist was paralysed in the right arm.

Acute mania may be manifested by pronounced irregularities in the writing, as is to be seen in writing of Lenau, the German poet. In other cases of insanity there may be not only alterations in the form of the writing, but also paragraphia, or the use of wrong letters.

It will be readily understood from this short summary of the various influences which may affect the form of handwriting that cases must frequently occur in which it is not possible to make any definite statement as to the authorship of a particular piece of writing. All that can be done by a specialist in the subject is to point out the points of resemblance and difference between two specimens, and to say what deductions may be drawn from them with a reasonable degree of probability. Conclusions drawn from even close superficial resemblances in form have over and over again been shown to be fallacious, and positive assertions, such as have frequently been made in Courts of Law, are seldom, if ever, justifiable.

The problem may be present itself in various forms, such as anonymous letters, where there will be a presumption that the real writing will be disguised; and cheques or other documents alleged to have been forged, where attempts will have been made to imitate the handwriting of someone else. In the second case, viz., the alleged forgery of writing, it may be necessary to see how far the facts support a denial that a particular piece of writing was written by a particular person. Even when there is exact similarity in the form of the writing, together with correspondence in the kind of ink, there may still remain the bare possibility of the work being that of an abnormally clever forger, and if the facts are demonstrated and this possible conclusion also pointed out, it will then be a matter for the Court to decide how far it was probable that an abnormally clever forger could have been introduced into the case.

This is the form in which the evidence was presented in the case of the *Bishop of Lincoln* v. *Wakeford*, and that course met with the approval of the Lord Chancellor, who, in the course of his judgment, remarked:—"This is the manner in which expert evidence on matters of the kind ought to be presented to the Court, who have to make up their minds, with such assistance as can be furnished to them by those who have made a study of these matters, whether a particular writing is to be assigned to a particular person."

In cases of the first type (anonymous letters) the documents may possibly have been written (*a*) by a suspected person; (*b*) by some one else whose writing may or may not normally show many points of resemblance to that of the suspected person; (*c*) by someone who has attempted to imitate the writing of the suspected person; (*d*) by the recipient of the anonymous letter.

In the first case (*a*) it will usually be found that the manifest form-characteristics of the writing are disguised, and it will be necessary to look for the less obvious points of resemblance and difference between the anonymous writing and that of the suspected person.

In the case of (*b*) there will presumably be obvious points of resemblance with both the anonymous and suspected writing, but minute resemblances only with the anonymous writing and differences from the writing of the suspected person.

In the case of (*c*) the writing may show even more obvious resemblances with the writing of the suspected person, but will at

the same time show pronounced differences in the less obvious details.

In (*d*) some of the obvious characteristics and many of less obvious ones may be found in common between the anonymous writing and that of the recipient.

It should be the work of the specialist to demonstrate in which of these directions the balance of probability lies, and to leave it to the Court to decide which conclusion is most in keeping with the other evidence in the case.

From what has been said it is manifest that the inferences to be drawn from the examination of handwriting will vary in their degree of probability just as in the case of all other evidence.

When there is a large quantity of writing available and numerous points of resemblance between the writing and the admitted specimen are present and no material points of difference, the conclusion will obviously carry more weight than when the points of resemblance and difference are more evenly balanced.

Similar variations in form between the individual letters in two specimens of writing are more valuable criteria of identity than mere similarity of form, and it was for this reason that the words on the stave in the "Membland" case were probably in the handwriting of one of the members of the crew, for it is unlikely that all these like variations in form should have been the result of chance or the work of a forger.

A too obvious similarity in form has occasionally proved fatal to the claim of a forger, for it has exceeded the limits of reasonable probability. Since it is necessary that a simulated signature should closely resemble the original in form, attempts have not infrequently been made to reproduce the genuine writing by means of tracing. Frequently, a traced signature may show indications of uncertainty or irregularity, but it will be obvious from what I have said about the influence of pathological conditions on writing that such variations from the normal condition may be at most suspicious circumstances.

In certain cases, however, the original model from which the copy has been traced has been found, and the exact correpondence in form between the two writings has been too remarkable to admit of the possibility of its being due to coincidence. In an American case of this kind mathematical evidence was given that the probability of two such signatures exactly coinciding in every stroke was one chance in 931 quintillions.

In another celebrated trial, known as the Rice-Patrick case, it was demonstrated conclusively by Mr. A. S. Osborn, of New York, that the four signatures of an alleged testator on a will coincided in the relative positions of all the letters, whereas five genuine signatures of the deceased showed pronounced differences in form, position and intensity of pigment. The agreement between the four signatures on the will was clearly shown by various scientific measurements, such as photography beneath glass divided into a series of equal squares.

Alterations and erasures in writing may usually be made manifest by means of enlarged photographs, and the conversion of, say, a "1" into a "7", which would escape the notice of a casual observer, will be readily visible in the writing enlarged to several diameters.

In some instances it is even possible to ascertain which portion of two intersecting strokes of writing is uppermost, and so prove which of the two was written first. The value of such observations was shown in the case of *Rex v. Cohen*, where it was an important factor contributing to the acquittal of the accused person.

In the Rice-Patrick case we have a good example of the use of scientific methods in the examination of handwriting. It is obvious, however, that instances of a similar kind will only be of exceptional occurrence, and that the procedure will not be applicable to most of the problems which have to be solved, and for which, as a rule, other methods must be used.

It may be accepted as an axiom that no branch of human enquiry can be regarded as scientific in character until exact quantitative measurements can be applied to its interpretation. The use of such measurements in the examination of handwriting was first devised by Persifor Frazer, some twenty years ago, and has more recently been extended and perfected by Dr. Locard, of Lyons.

The principle upon which measurements of the kind are based is the observed fact that although a person's writing may vary in size, slope or formation, yet the average quantitative relationship between parts of a letter and the whole letter, and between individual letters and words will usually be preserved. For example, the

space between the sides of the loop of the letter "b" will stand in a certain proportion to the height of the letter, and so on.

The number of such possible relationships is very large, and the results can be expressed in the form of diagrams which can be readily compared with those based on similar measurements of letters in an admitted writing. Among the measurements which Dr. Locard has found to be of the greatest use are the following:—

(1) The ratios in which the heights of small letters (omitting those which, like "p" or "t" extend below or above the line), stand towards each other.

(2) The ratios between the angles of letters, measured in a definite manner, and the heights of the letters themselves.

(3) The frequency with which the pen is lifted in words containing different numbers of letters.

(4) The frequency with which different formations of dots to the letter "i" are present.

The use of such methods of measurement implies a considerable amount of writing being available for comparison and measurement of similar words and letters, but a modification of the method can sometimes be used with good results, even for the comparison of signatures.

Through the kindness of Lord Salisbury and the Librarian at Hatfield House (The Rev. W. Stanhope-Lovell), I have recently had the opportunity of examining some of the original letters of Mary Queen of Scots, which are preserved at Hatfield, and have applied to some of them quantitative measurements similar to those mentioned. Among the letters to which I have applied these tests is the well-known "Scandal Letter" which Mary is said to have written to Queen Elizabeth. Some doubt has been thrown on the authenticity of this letter by Mr. F. Chamberlin, in his *Private Character of Queen Elizabeth*, but an examination of the writing affords no reason whatever for the belief that the letter is other than genuine.

It is essential, of course, that whatever forms of measurement and comparison are adopted, the same routine should always be followed. The results thus obtained are far more trustworthy as criteria of probability than those obtained by a mere qualitative comparison of the forms of the characters, and it is hardly going too far to say that if such measurements had been applied scientifically in many of the notorious cases of the past, we should have had few miscarriages of justice through the mistaken identification of handwriting.

DISCUSSION.

THE CHAIRMAN, in opening the discussion, said it was, of course, impossible that evening to discuss or criticise with any valuable result a paper which travelled over so wide a range as that which had just been read, but possibly by way of starting the discussion upon such an extremely interesting subject the audience might like to hear from him as Chairman a few observations on the paper. He and many of those who were listening to him were interested in the question as it applied to the detection of crime. The title of the paper showed that that was the object which the author had in view, and while he thoroughly appreciated the possibilities of the scientific methods, which Mr. Mitchell had so clearly explained by means of the diagrams, of making handwriting a more dependable class of evidence, the common view of handwriting which Mr. Mitchell as a scientific man so much despised was the one which was most likely to be the faithful handmaiden of those who were engaged in the detection of crime and the identification of the persons who were guilty of it. At present, however, that vulgar view of handwriting, although exceedingly useful, was not very trustworthy, and if the scientific methods to which the author had referred could be sufficiently developed to be understood, not only by every mother's son who happened to be on a jury, but by every son's mother as well, some advance would have been made towards the end which the author and everyone had in view.

Perhaps it might be useful if he were to refer to some instances which had come into his personal experience. There were many persons who were natural judges of handwriting. They could identify a known handwriting at a glance by an address on an envelope containing a letter. Among such natural judges of handwriting there was no more trustworthy class (if he excepted ladies) than managing clerks to solicitors. He had been fortunate enough to have among his acquaintances a managing clerk to a solicitor whom he regarded as a masterly judge of handwriting. The foot of clay was revealed in the following manner: His acquaintance had pointed out to him a handwriting which was clearly identifiable with that in the attendance book at a gambling club. The visitor had signed the name of "Mr. Smith." and it was quite clear, in the view of that excellent judge of handwriting—his acquaintance—that the handwriting was that of Mr. Brown. He himself had looked at the genuine and

undoubted hand of Mr. Brown and had also looked at the signature of Mr. Smith, and he had been convinced by his own eyesight as well as by the judgment of his friend that that was the handwriting of Mr. Brown. Among other witnesses called to prove who the frequenters of that gambling club were, was the man who stood at the door and who only admitted those persons who were entirely trustworthy. He was asked to identify the various signatures in various false names in the book, and he identified them to the prosecution's entire satisfaction until he got to the signature of Mr. Smith. He was asked "Do you know that handwriting?" and he replied "Yes. I know it quite well." "Whose is it?" "It is mine."

He (the Chairman) had been so astonished that he asked the man to write the name "Mr. Smith" with the Christian name. The man had done so, and it was identical. In that case, therefore, despite his own eyesight and the judgment of his friend, the handwriting had been no trustworthy evidence at all. Another instance of the unreliability of handwriting had come under his notice. It had been one of those cases which was now engaging a good deal of attention, and which might be tersely described as murder by post, in which the only means of identifying the person who sent the bomb, or poison or other murderous missive was the handwriting of the address on the parcel, or the handwriting which might be contained inside. In the documents in question, one particular letter of the alphabet occurred over and over again in a form in which he personally had never seen that letter written before. It was in the undoubted handwriting of the suspected person. He had regarded that letter as being absolutely unique, and there it had been upon the parcel which had contained the murderous contents. He had thought that that was quite conclusive by itself, until he had discovered that the same letter was written in exactly the same way by the gentleman who was giving him instructions. It did not want more than those two illustrations to show that the vulgar view of handwriting—that was to say, the identification by looking at peculiarities of individual letters—was not entirely trustworthy. At the same time, it was exceedingly useful, and nothing was more likely to lead to the detection and the identification of a person sending such missives than the methods which were resorted to by the police, of publishing the handwriting of the document which identified the criminal in the press, or upon the screens of the picture palaces—although the latter method had led to different results, as might be mentioned in the course of the discussion. It might be interesting to those whom he was addressing to know that within the range of his own experience, which now covered a good many years, the way of transgressors had become increasingly hard. When he first began to practise at the Criminal Bar, and a man was found with blood stains upon his clothes or hands, it could not be said whether they were those of a human body, or the body of a pig or ox or a rabbit. Therefore, a man who was a butcher or even a poacher, might give a different reason for the existence of those stains than the true one. Since then science had discovered the means of discriminating between blood stains of different mammalian animals. Mr. Mitchell had been instrumental in the conviction of a forger who sought to imitate the signature and the handwriting generally to the will of a lady, which the forger dated about twenty years back. Mr. Mitchell, by a few simple tests, disclosed the fact that that writing had not been more than eighteen months old at the outside The fact was that science had made things very hard for the criminal, and in the matter of handwriting, judging by what had been said that night, the criminal seemed to be very hard pressed. He had observed that one of the illustrations shown by Mr. Mitchell had been a certificate by a Magistrate with regard to the burial of a body in wool, which had been the first method of the registration of deaths or burials which ever had happened in England. In Scotland centuries before, they had had regular registers of births and burials, which showed if it had not been for the annexation of England by Scotland, things would still have been very bad in this country!

Mr. Mitchell had pointed out the true value of handwriting and the principal place of experts in a body of evidence designed to show guilt in a prisoner, or the true authenticity of a disputed handwriting. Handwriting was an excellent detector. The detective's business was to point out the true criminal or the true author of the handwriting in dispute. It was the business of the lawyers to produce the other evidence which Mr. Mitchell said was the true test of all questions of disputed handwriting. It was said years and years ago of a detective inspector in the East-end of London, that when he knew who the true criminal was that criminal was not going to get off for the want of a little bit of evidence. The difficulty with regard to the diagrams which had been shown on the screen of Dr. Locard's method would, he was afraid, be in making that method understood by a Jury. He did not think anybody would ever suggest that all questions of disputed handwriting should be referred to experts like Mr. Mitchell—if, indeed, twelve such experts could be collected from the four ends of the earth. They would have to be submitted to a Jury, and his criticism upon Dr. Locard's method was that it would have to be convincingly proved to the Jury that that method was infallible before a Jury would accept it. He did not say that was impossible. It had happened in regard to finger prints. Finger prints had been demonstrated to Jury after Jury to be infallible.

To those of his audience who were thinking of committing crimes, let him warn them not, upon a hot summer night, to grasp a beer bottle too firmly, because the identification glands of the fingers were the sweat glands, and the black japanned cash box containing the money which they were anxious to possess themselves of by means of the burglary which they were contemplating, was the most favourable receptacle possible for finger prints, except a beer bottle.

To those of his audience who were thinking of forgery rather than burglary as a method of adding to their income, by the aid of science, hypnotism rather appealed to him, but he should like his hypnotist to be thoroughly acquainted with the handwriting of one of the Rothschilds, or some gentleman whose signature would be accepted with equal facility by the Bank of England. If he might tell his listeners how he should forge the signature of Mr. Rothschild, what he should do would be to procure a large number of genuine signatures of Mr. Rothchild's and a cheque form from his cheque book, and then——well, perhaps he had better not continue!

Dr. A. M. Gossage, C.B.E., said he had had no experience of comparing handwritings with respect to the question of identification. All he could say on the matter was in the way of adding to what Mr. Mitchell had said about the immense value of science in investigating any method of identification either by handwriting or any other way. We were probably only on the threshold of the question of properly regarding handwriting in a scientific way. By further research very much more definite methods of identifying individuals' handwriting would probably be discovered. One was reminded, on the question of handwriting, of many other ways in which evidence was brought before a Court of Law—for instance, the identification of an individual by various people who knew what that individual looked like. Everyone knew how often that method had failed by people being wrongly identified by somebody else. There were now scientific ways in which a man could be identified with absolute certainty. Mr. Mitchell had touched on the question of the recognition of relatives by their resemblances. He had touched on it in regard to the question of handwriting, but the same thing was employed in the Courts where they tried to recognise whether people were related by the fact of their resemblance in personal appearance. That was a very dangerous method of recognising relatives, particularly when it came to the question of recognising a child by its resemblance to the supposed parents. Scientific methods were beginning to be evolved of seeing whether a certain child could be the child of certain parents. There was not a positive method of saying that it was the child of certain parents, but there was a method of saying whether it could or could not be the child of certain parents—which was a very great advance. For instance, it was known that two parents with blue eyes could not have a child with brown eyes, although it was known that two parents with brown eyes might have a child with blue eyes. Again, two parents with red hair would produce children with red hair, but a red-haired child cropped up sporadically from people who had got less highly-coloured hair. That illustrated how it was possible by scientific methods to add to the certainty of those various questions which came up in Courts of Law, and an enormous amount of work was still to be done in making more certain those various questions by identification, both of the individual and of the handwriting.

Mr. Percival Clarke said he could claim to have had some experience with regard to the value of handwriting as evidence. The first case which he could recall was that of Adolph Beck who, as it turned out afterwards, was wrongly convicted. It was an interesting case because, at the time, so much depended upon the question of the identification of the man who was charged. One of the methods employed in order to bring home to that unfortunate person the guilt of the crime with which he was charged was that it was sought to be proved that certain documents which the criminal had given to persons who had been defrauded were in the handwriting of Adolph Beck. At the time there had been one great expert of handwriting, well-known for his absolute fairness who, if he had been permitted to give evidence in that case, was prepared to produce evidence which would have absolutely cleared Adolph Beck from the charge brought against him.

The person who had committed the offence was an individual who had given certain people lists of costumes, boots and so on with which they were to provide themselves, and also cheques, which were all written undoubtedly in the same handwriting—the handwriting of a foreigner. It was quite easy for anyone looking at ordinary writing, to see whether it was written by an Englishman or a foreigner. The characteristics of a foreign handwriting could be detected, although it might not be known whether it was that of an Italian or Spaniard or Norwegian, but it could be seen that it was not English. There was no doubt that the exhibits in the Adolph Beck case were in the handwriting of a foreigner. Adolph Beck happened to be a Scandinavian. The documents had been put before the leading handwriting expert of the day, who reported that he saw similarities which made him think that the lists of addresses and cheques which had been produced by the people defrauded were in the disguised handwriting of Beck, but he would not go beyond that. Beck had had

a strange career. He was an elderly man at the time of the charge, in 1876. He had been engaged in some enterprise with Colonel North in either Chile or Peru. In the archives of the Old Bailey there was a record that a person had been charged in 1875 with an exactly similar offence to that with which Beck was charged. The documents which had been exhibited in that case were still retained among the archives at the Old Bailey, and the Treasury asked the leading expert of the day to compare the cheques and lists of addresses in the Beck case with those which had been exhibited in exactly similar frauds in 1875. The expert did so, and stated that although he would say to the best of his belief that the cheques and lists of addresses were in the disguised handwriting of Adolph Beck, he entertained no doubt whatever that they were written by the same man who had written the documents in 1875. The man who had been the cause of those originals being brought to the Old Bailey in the earlier case was called John Smith, who had been convicted at the trial and sent to penal servitude for the offence which he had committed, and he was serving that time of penal servitude when Adolph Beck was with Colonel North. The expert was thoroughly right, and was perfectly fair in his view—that those exhibits were in the disguised handwriting of the prisoner, but he did not doubt that they were in the same handwriting as those in 1875 of John Smith. However, that evidence was not allowed to be given, and Adolph Beck was sentenced to a term of seven years' penal servitude. He served that time, and when he had finished it he came to his (Mr. Percival Clarke's) chambers, and said: "I have done my term. I do not ask for any recompense, but I have been an honest man, and I want to go back to my people with my name cleared. How can I do it?" He was told to find John Smith, and after a considerable amount of trouble John Smith was found and eventually confessed to the crime. He (Mr. Percival Clarke) had entertained at the time a very high opinion of that expert in handwriting; he had been right. As he (Mr. Percival Clarke) had gone on to see other cases of similarities in handwriting pointed out by experts, he had come to the conclusion that where one did see, as the expert had seen in the Adolph Beck case, marked similarities in numbers, it was impossible, or well-nigh impossible, that the identity of the person who wrote the documents could be mistaken.

Then there was the Bournemouth murder case. There was found the value of Mr. Mitchell's suggestion of photographing the handwriting and exhibiting it upon the screens of picture palaces. The murdered woman had been induced to go to Bournemouth by reason of a telegram. The Police had had the writing on the original telegraph form photographed and put on the screens of all the Bournemouth picture palaces. The guilty man saw it, and immediately altered his handwriting, so that what had been previously a slope from right to left became from that moment a slope from left to right; but the characteristics of the handwriting remained and the mistakes in spelling remained. When that man came to take his trial one of the most potent factors in securing the just conviction of a guilty man was the undoubted similarity of the handwriting between his own admitted handwriting and that on the telegraph form. Although the man protested his innocence, before the final act he acknowledged the justice of the conviction which had been recorded against him. Those two instances had helped to convince him that there was a very great value indeed to be attached to handwriting as evidence of guilt.

There was one other case which he might mention in which Mr. Mitchell had taken a prominent part. It was a case where an attempt had been made to obtain money, by a person falsely pretending that an acknowledgment of, say, £1,000 was a genuine document, when, in fact, it was only an acknowledgment of £100. Mr. Mitchell had been not only able to indicate beyond all question that the original sum mentioned had been £100 and that the final nought had been added, but he had been able to show by means of a photograph that it had been added in a different kind of ink.

Mr. R. a'Ababrelton said that in two cases, at least, it had been stated that the finger prints had failed as means of identification. With regard to handwriting, he mentioned a case where a private secretary to a gentleman always wrote the signature of his principal on cheques, in times of pressure, which cheques were always passed by the cashier at the Bank in the ordinary way, notwithstanding the signatures being by two different persons.

Mr. G. Guerin said with regard to Dr. Locard's system, the difficulty which he found with it was that although it was based on a definitely scientific and absolutely accurate method, in point of fact, when one came to work out the various constructions which Dr. Locard gave, one found that the human element did enter into it. For instance, as the audience would have seen on some of the diagrams which had been exhibited that night, a directional line had to be taken as indicating the direction of a curve or of a loop. The slightest divergence one way or the other, which was very easily possible, made an enormous difference on the actual chart when it came to be plotted. It was in that respect that the method did allow the human element to creep in. Nevertheless, he thought it would probably be found in the future that there was a very great deal in Dr. Locard's method, and that it would help

to an enormous degree to put the question of identification by means of handwriting on that solid basis on which all those interested were so anxious to see it.

Mr. Mitchell had, to some extent at any rate, placed the expert in a very much higher position than Sir Richard Muir desired to place him, for the reason that Sir Richard Muir was anxious that the every-day knowledge of the man in the street with regard to handwriting should be recognised. In his own opinion the true line was somewhere between those two. The ultimate person who had to decide the question (in most cases, at any rate) was the man in the street—the Juryman, and he had to decide on the facts which were pointed out to him by somebody whose main qualification really was that he had had the time and the experience for closely examining handwriting. If the facts were put before a Jury in a perfectly plain and comprehensible way, then the Juror of to-day was quite capable of understanding those facts and of coming to a just conclusion upon them. At any rate, that was his own humble experience.

Mr. A. C. Fox-Davies said there was one point which he had never yet succeeded in getting a handwriting expert to admit to him in cross-examination, and that was that the same person might have two absolutely distinct handwritings in which there was no similarity at all. Such a thing did exist, however, because he himself could write two distinct handwritings. He happened, for a period, to have been private secretary to an old Quaker, who insisted upon his adopting a copper-plate handwriting. In order to please his principal he had adopted copper-plate handwriting, but at the same time tried to retain his own individuality in his handwriting, with the result that at the present time he could write two perfectly distinct handwritings.

Another point was the difference in the same person's handwriting when it was written with a pencil and when it was written with a pen. A great many people wrote on the point of a pencil, and, consequently, were inclined to write at a more upright angle and unconsciously to form their letters in a different way than when they wrote with a pen.

Mr. Mitchell, in reply, said he had been much interested in the Chairman's exposition of his *vade mecum* for budding criminals, but he had been disappointed that the Chairman had not quite completed it. What he had said, however, had been very interesting as showing the difficulties which did attend any judgment on handwriting. There were some people who were naturally instinctive judges of handwriting, but how far they would stand cross-examination by the Chairman he did not know.

With regard to the difference of opinion between specialists, the methods, of course, were not infallible. After all, it was only human judgment. That was a point which he had been trying to bring out quite clearly—that one must not dogmatise; all one could do was to try to point out where the similarities and dissimilarities were. It had often occurred to him that where there was a dispute as to the interpretation of scientific facts, it would be a very good thing if it could be referred to a trained scientific man, who would take written views from both sides and interpret them. As a rule, a judge was not trained to do that. He thought there was a precedent for such a thing in a murder trial somewhere about 1857. Medical and chemical evidence had been given on the one side, and on the other, and the then Home Secretary had referred the matter to Sir Benjamin Brodie, who eventually said that there were six reasons for accepting the opinion of the witnesses for the prosecution, and eight reasons for accepting the opinion of the witnesses on the other side. The result was that the man was released.

With regard to Mr. a'Ababrelton's remarks about finger prints, he would want a good deal of evidence to convince him that finger prints were unreliable. He quite agreed with Mr. Gurrin's remarks about the human element entering into the measurement of the angles, but this did not apply to the measurement of the heights of the letters.

In regard to Mr. Fox-Davies's remarks on his dual handwriting, it was quite likely that if Mr. Fox-Davies wrote a long letter, some of his natural characteristics would creep out in it.

NOTES ON BOOKS.

Glass Making in England. By Harry J. Powell, C.B.E. Cambridge: at the University Press. 25s. net.

The late Mr. Harry J. Powell—unfortunately he did not live to see the publication of this volume—was a well-known Fellow of the Royal Society of Arts, for he read a number of papers here—the last in 1919, on "Glass-Making before and during the War." In the opening passage of that paper he mentioned the fact that it was just forty-four years since, a very young manufacturer of about six weeks' standing, he had read his first paper in that room. During the long years that elapsed since that first appearance Mr. Powell was a diligent student of glass manufacture in all its aspects, scientific, artistic, historical and commercial, and the present volume sums up the essence of the great knowledge which he acquired.

This seems to be the first real attempt to write the history of glass-making in England. Glass was introduced into this country by the Romans, and a number of illustrations give interesting evidence of the state of excellence

which the glass blowers possessed at that period. It would appear, however, that at this time very little, if any, glass was made in England: "the similarity in form, and in chemical composition of Roman glass vessels whether found in England or the Continent, in Syria or Egypt, makes it probable that there were only a few centres of glass manufacture, and that the vessels were distributed from these centres through the whole Empire." But by the thirteenth century England boasted quite a considerable glass trade, whose principal centre was at Chiddingfold, near Haslemere. An interesting account is given of the industry as practised there, together with illustrations of the bee-hive shaped glass ovens and glass-making tools.

A chapter describing the influence of foreign glass-makers on the British industry is worth careful study, and the author has been at pains to compile a list of the chief of those foreigners who settled in this country between 1568 and 1738.

By the middle of the eighteenth century there were numerous glass houses in England. A map of London in 1760 shows the sites of about twenty.

Coming to recent times Mr. Powell, fittingly enough, gives some account of the famous Whitefriars Works, whose activities for so many years he directed. The writer of this note had the pleasure of being taken over the works by Mr. Powell about a year ago, when he was entranced to watch the skill of the workmen in turning out delicate wine glasses, rose bowls, etc. For over two centuries the firm carried on business on this historic site. We could wish that Mr. Powell had permitted himself to give us a little more of the human element in the history of his works: a few more glimpses like the following would surely not have been out of place:—

"Perhaps one of the most interesting and interested visitors to the works was John Ruskin. He showed a curious liking for brilliant and crude colours, and he recommended Miss Kate Greenaway as a designer for painted glass, whose drawings were singularly ill-adapted for glass technique. In the studio he took off his hat before the laboured and ineffectual drawing of a very young artist, because the effort bestowed upon the shading of an angel's wings, for a window to be fixed at a great height from the ground, although unseen by men, would be appreciated by angels in heaven."

MEETINGS OF THE SOCIETY.

Ordinary Meetings.

Wednesdays at 8 p.m., except where otherwise stated:—

April 18 (at 4.30 p.m.).—Hal Williams, M.I.Mech.E., M.I.E.E., M.I.Struct.E., "Modern Abattoir Practice and Methods of Slaughtering." W. Phené Neal, Alderman of the City of London, late Chairman of the Cattle Markets Committee of the Corporation, will preside.

April 25 (at 4.30 p.m.).—Conference on "The Milk Question." Short papers will be read as follows:—(1) Professor R. Stenhouse Williams, M.B., B.Sc., L.R.C.P. and S.E., D.P.H., "The Arguments for Maintaining an Open Market for Fresh Milk;" (2) Professor J. Cecil Drummond, D.Sc., F.I.C., "Changes in the Digestibility and Nutritive Value of Milk induced by Heating;" (3) S. S. Zilva, Ph.D., D.Sc., F.I.C., "The Effect of Heat on some Physiological Principles in Milk." A Demonstration of some of the Chemical Changes in Milk on Heating to various Temperatures will be given by Captain John Golding, D.S.O., F.I.C. and Mrs. A. T. R. Mattick. M.Sc. The Right Hon. F. D. Acland, M.P., will preside.

May 2.—Maurice Drake, "The Fourteenth Century Revolution in Glass Painting." Professor W. R. Lethaby will preside.

May 9.—William Arthur Bone, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Surface Combustion, with special reference to recent Developments in Radiophragm Heating."

May 16.—L. Gaster, "Industrial Lighting and the Prevention of Accidents."

May 30 (at 4.30 p.m.).—A. J. Sewell, "The History and Development of the Perambulator and Invalid Carriage."

Indian Section.

Friday afternoons.

June 1, at 4.30 p.m.—Austin Kendall, I.C.S., rtd., "The Indian Section of the British Empire Exhibition, 1924."

June 15, at 4,30 p.m.—Sir John H. Marshall, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture.)

Dominions and Colonies and Indian Sections. (Joint Meeting.)

Friday, April 20th, at 4.30 p.m.—Sir

RICHARD A. S. REDMAYNE, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S., "A Review of the Base Metal Industry, with Special Reference to the Resources of the British Empire." The RT. HON. LORD EMMOTT, G.C.M.G., G.B.E., will preside.

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

E. KILBURN SCOTT, Assoc., M.Inst.C.E., M.I.E.E., "The Fixation of Nitrogen." Three Lectures. April 9. 16, 23.

Syllabus.

LECTURE II.—Calcium cyanamide process Work of Frank, Caro, etc.; Electric furnaces for Calcium carbide, etc. Methods of preparing pure nitrogen; Plants on the Continent and in America; Products: Ammophos, ammonia sulpate, ammonia nitrate, etc. Other processes: Hausser-explosion process, cyanide, etc.,

LECTURE III.—Synthetic ammonia process. Work of Haber, Le Rossignol, etc.; Methods of making pure hydrogen; Types of catalysts: chrome steel bombs; Plants at Oppau and Merseberg; Employment of extra high pressure by Claude; Products. Oxidation of ammonia. Work of Ostwald, Partington, Parker, etc.; Necessity of platinum catalyst.

HOWARD LECTURES.

Monday evenings at 8 o'clock.

STANLEY S. COOK, "Recent Improvement in Steam Turbines." Three Lectures. April 30, May 7, 14.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, APRIL 16 .. Geographical Society, Lowther Lodge, Kensington Gore, S.W., 5 p.m. Mr. W. Irwin, "The Salts of the Dead Sea and River Jordan."

TUESDAY, APRIL 17 .. Statistical Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.15 p.m.

Royal Institution, Albemarle Street, W., 3 p.m. Sir Arthur Keith, "The Machinery of Human Evolution." (Lecture II.)

Asiatic Society, 74, Grosvenor Street, W., 4.30 p.m. Mr. F. E. Pargiter, "The God Indra and Religious Contests in Ancient India."

Transport, Institute of, at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C., 5.30 p.m. Mr. H. E. Blain, "The Prevention of Traffic Accidents."

Marine Engineers, Institute of, 65, The Minories, E., 6.30 p.m. Mr. R. Clark, "The Operation of Water-Tube Boilers for Cargo and Passenger Ships."

Anthropological Institute, 50, Great Russell Street, W.C., 8.15 p.m. Miss Tyra de Kleen, "The Ceremonial Dances and Magic Rites of the Island of Bali, Dutch East India."

Photographic Society, 35 Russell Square, W.C., 7 p.m. Mr. J. C. Dolman, "Similar Difficulties in Painting and Photography."

Victoria League, Denison House, Vauxhall Bridge Road, S.W., 5 p.m. Sir Benjamin Robertson, "In Field and Forest in the Central Provinces of India."

Travellers Aid Society, Imperial Institute, South Kensington, S.W., 3 p.m. Mr. G. de Hochepied Larpent, "The Romance of Rhodesia."

WEDNESDAY, APRIL 18 .. Historical Society, 22, Russell Square, W.C., 5 p.m. Carre Emelio, R.E., "The English Colony in Rome during the 14th Century."

Meteorological Society, 49, Cromwell Road, S.W., 5 p.m. 1, Messrs. W. H. Dines, and L. H. G. Dines, "An Examination of British Upper Air data in the light of the Norwegian theory of the structure of the Cyclone." 2, Mr. T. Kobayasi, "On the Mechanism of Cyclones and Anti-cyclones." 3, By Capt. E. C. Shankland, "Notes on the fluctuations of mean-sea-level in relation to change of atmospheric pressure, from observations at Liverpool, August and September, 1920."

Microscopical Society, 20, Hanover Square, W., 8 p.m. 1, Dr. W. B. Brierley, "The Microscope in Agricultural Research." 2, Prof. A. C. Seward, "The Use of the Microscope in Palæobotanical Research." (Industrial Applications Section), 7 p.m. Mr. D. W. Cutler, "The Protozoa of the Soil."

Geological Society, Burlington House, Piccadilly, W., 5.30 p.m. Mr. J. F. N. Green, "The Structure of the Bowmore-Portaskaig District of Islay."

THURSDAY, APRIL 19 .. Royal Society, Burlington House, Piccadilly, W., 4.30 p.m.

Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.

Constructive Birth Control, Essex Hall, Essex Street, W.C., 8 p.m. Mr. C. E. Pell, "Is the Fall in the Birth Rate a Natural Law?"

Mining and Metallurgy, Institution of, at the Geological Society, Burlington House, Piccadilly, W., 5.30 p.m. 1, Mr. W. B. Pollard, "The Titration of very small amounts of Gold." 2, Mr. W. A. Heywood, "Notes on the Selection of a Copper-Smelting Plant."

Royal Institution, Albemarle Street, W., 3 p.m. Prof. A. O. Rankine, "The Transmission of Speech by Light." (Lecture II.)

Linnean Society, Burlington House, Piccadilly, W., 5 p.m. 1, Mr. E. Heron-Allen, and Mr. A. Earland, "The Foraminifera of Lord Howe Island, South Pacific." 2, The General Secretary, "The History of Botanic Illustration in Colour during Four Centuries."

Chemical Society, Burlington House, Piccadilly, W., 8 p.m. K. Ibbotson and J. Kenner, "The Influence of nitrogroups on the reactivity of substituents in the benzene nucleus. Part VII. Reactions of 2:5— and 4:5— dinitro-*m*-xylenes." S. F. Birch, G. A. R. Kon and W. S. G. P. Norris, "The Chemistry of the three-carbon system. Part I. The Influence of the *Cyclo*hexane ring on the ab—by change." S. Medsforth, "On the promotion of catalytic reactions. Part I."

Transport, Institute of, at the Geographical Society, Manchester, 6 p.m. Mr. W. H. Breach, "The Work of the Air and Calder Navigation."

Structural Engineers, Institution of, at the Institution of Civil Engineers, Great George Street, S.W., 7.30 p.m.

FRIDAY, APRIL 20 .. Engineering Inspection, Institution of, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 7.30 p.m. Mr. C. H. Richardson, "The Inspection of Ball Bearings."

Royal Institution, Albemarle Street, W., 9 p.m. Mr. W. J. S. Lockyer, "The Growth of the Telescope."

Sanitary Institute, Nottingham. Discussion on Local Authorities and the Venereal Diseases Problem."

SATURDAY, APRIL 21 .. Royal Institution, Albemarle Street, W., 3 p.m. Sir Owen Seaman, "Sonnets and Ballads of Dante Rosetti." (Lecture II.)

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FRIDAY, APRIL 20, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICES.

NEXT WEEK.

MONDAY, APRIL 23RD, at 8 p.m. (Cantor Lecture). E. KILBURN SCOTT, Assoc.M. Inst.C.E., M.I.E.E., "Nitrates from Air." (Lecture III.)

WEDNESDAY, APRIL 25TH, at 4.30 p.m. (Ordinary Meeting). Conference on "The Milk Question." Short papers will be read as follows:—(1) PROFESSOR R. STENHOUSE WILLIAMS, M.B., B.Sc., L.R.C.P. and S.E., D.P.H., "The Arguments for Maintaining an Open Market for Fresh Milk;" (2) PROFESSOR J. CECIL DRUMMOND, D.Sc., F.I.C., "Changes in the Digestibility and Nutritive Value of Milk induced by Heating"; (3) S. S. ZILVA, Ph.D., D.Sc., F.I.C., "The Effect of Heat on some Physiological Principles in Milk." A Demonstration of some of the Chemical Changes in Milk on Heating to various Temperatures will be given by CAPTAIN JOHN GOLDING, D.S.O., F.I.C., and MRS. A. T. R. MATTICK, M.Sc. THE RIGHT HON. F. D. ACLAND, M.P., will preside.

COUNCIL.

The Council at their last meeting elected Dr. J. A. Voelcker, a member of the Council and Vice-President of the Society, in place of Lord Sanderson, G.C.B., deceased.

SEVENTEENTH ORDINARY MEETING.

WEDNESDAY, APRIL 11TH, 1923; CAPTAIN BERTRAM BROOKE, Tuan Muda of Sarawak, in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Anjaria, Hiralal Ganeshji, B.A., Godhra, India.
Aspar, P. E., A.M.I.N.A., A.M.I.Mech.E., Bombay, India.
Barooah, Gozendro Nath, Assam, India.
Bennet, Emile J., Torquay.
Carter, William Leslie, F.C.S., Birmingham.
Case, Theodore Willard, B.A., Sc.M., New York, U.S.A.
Duncan, Prof. David Shaw, A.M., B.D., Ph.D., Colorado, U.S.A.
Gilmer, Weir Burton, Tatapuram, India.
Kalyanray, Jhaverilal, M.I.M.E., Bengal, India.
Mackenzie, Captain Ian Alistair, M.A., LL.B., M.P.P., Vancouver, B.C., Canada.
Manuja, Jaswant Roy, Lahore, India.
Nagle, James C., M.A., B.Sc., Texas, U.S.A.
Pendleton, Robert Larimore, B.S., Ph.D., Gwalior, India.
Saunders, Miss Marshall, Toronto, Canada.
Vallis, Joseph Samuel, Bermuda, B.W. Indies.

The following candidates were duly elected Fellows of the Society:—

Assinder, G. F., M.A., B.C.L., LL.D., London.
Beit, Sir Otto, K.C.M.G., LL.D., London.
Gidney, C. W. A., Bhusaval, India.
Jain, Madan Mohan, Gwalior, Central India.
Marshall, Albert E., Baltimore, U.S.A.
Montgomery, George Hugh Alexander, B.C.L., K.C., Montreal, Canada.
Peterson, John Carlos Kennedy, C.I.E., Bombay, India.
Shank, Mrs. Edith Blanche, Coorg, South India.
Utley, Thomas, Liverpool.
Waring, Captain Harold, C.B.E., London.

A paper by MR. EDWARD PARNELL, late of the Sarawak Government Service, on "Sarawak: its Resources and Trade," was read by COMMANDER COLLINGWOOD HUGHES, M.P.

The paper and discussion will be published in a subsequent number of the *Journal*.

CANTOR LECTURE.

On MONDAY EVENING, APRIL 23RD, MR. E. KILBURN SCOTT, Assoc.M.Inst.C.E., M.I.E.E., delivered the second lecture of his course on "Nitrates from Air."

The lectures will be published in the *Journal* during the summer recess.

PROCEEDINGS OF THE SOCIETY.

DOMINIONS AND COLONIES SECTION.

6TH MARCH, 1923.

THE RT. HON. L. S. AMERY, M.P., First Lord of the Admiralty, in the Chair.

THE CHAIRMAN, in introducing the lecturer, said Major Belcher was a man of wide knowledge of the British Empire, and of amazing energy and perseverance, and had a great way of carrying through things which he started. He was going to speak about the importance of the British Empire and about the advantages of the Exhibition with which he was connected. That he could state his case plausibly and effectively was a matter to which not only would the audience bear evidence after they had heard the lecture, but which had also been confirmed by what the Chancellor of the Exchequer the previous evening had called the "acid test of finance"; because all the various Governments with whom Major Belcher had been in consultation, and with whom he had discussed the matter, had come forward and given very generous and whole-hearted support to the Exhibition, believing it to be not only of general value to the Empire as a whole, but a sound business proposition from their own points of view.

The address delivered was:

THE DOMINION AND COLONIAL SECTIONS OF THE BRITISH EMPIRE EXHIBITION, 1924.

By MAJOR E. A. BELCHER, C.B.E.,
Assistant General Manager, British Empire Exhibition.

When I was invited to address your Society on some subject in connexion with the British Empire Exhibition, I chose "Dominion and Colonial Sections of the Exhibition," because I thought it very important that your Society and the wider public to whom its activities are of interest, should get some conception of what this Exhibition means to the overseas Dominions, and in what way it may stimulate the development of our Imperial resources. If I tell you that the overseas portions of the Empire will occupy 700,000 sq. ft. of space at the Exhibition, that may or may not interest you, but if I say that this area is approximately twelve times the area occupied by the overseas Dominions at the Paris Exhibition of 1900, and approximately seven times that occupied at the Franco-British Exhibition, the figure becomes at least impressive. Perhaps I might put it in a still more interesting way. If you imagine the whole of the overseas Empire exhibits concentrated into one building, this building would occupy a space sufficiently large to drop Trafalgar Square in five times over, then to drop Olympia in, and there would be a balance left sufficiently large to accommodate the whole of the Army and Navy Stores on one floor.

It seems obvious to me that once you begin the organisation of exhibits on this scale, you are dealing with a group of countries that have not only got something very important to show, but some very solid reasons for showing it. Admittedly, there are always strong sentimental reasons which will attract the support of the Dominions in any Imperial undertaking, and such ties of sympathy and sentiment are very valuable. But it wants something even stronger than sentiment to induce a Dominion to pull a quarter of a million sterling out of its pocket and to spend it on the construction and equipment of a building 12,000 miles away. I suggest that Imperial sentiment persuaded Dominion Governments to lend a willing ear to the conception of a British Empire Exhibition, but that hard-headed business persuaded them that if it was worth doing at all, it was worth doing well. It is not given to all of us to have the unique advantage of travelling round the Empire and seeing with our own eyes its development and its resources. There is, however, no reason why every man, woman and child in this country should not get the next best thing at the Exhibition, and see with their own eyes something of the products, activities and even social life of each part of this great Empire. It is for that reason that in the lay-out of the Exhibition we have arranged that certain sections shall be ringed in as Dominion territory. Within these sections each Dominion has complete autonomy, and will endeavour to present so vivid a picture of its varied resources and activities, that for the nonce at all events, the visitor may get a real picture of Dominion life, and fancy himself on a voyage of discovery to the Western Continent and the Southern Seas or the Far East.

But that is only the beginning. Where is it to end? There are three things which the Dominions want, and they are more population, more capital and more markets. There may be others,

but it is to be presumed that one of the reasons which have induced such whole-hearted support of the Exhibition is a belief that by bringing home very vividly to the attention of the Old World the attractions which the New World can offer, the Dominions hope to enlist the intelligent attention of visitors of the Exhibition to their respective development.

We have in the United Kingdom a little over 100,000 square miles, with a population of a little under 50,000,000. New Zealand is about the same size, and has approximately one-fortieth of the population. Western Australia is ten times the size, and has a quarter of the population of the city of Birmingham. The Sudan is ten times the size and has half the population of London. One might go on almost indefinitely with statistics of this description, but you can see them for yourselves on page 488 of the current number of Whitaker, and you can amuse yourselves with working out some very interesting comparisons, not only between this country and different parts of the Empire, but between different parts of the Empire alone. Nigeria, for example, is three times the size of the United Kingdom, and has about a third of the population, but it is also only one-third the size of Western Australia, and has three times the population of the Commonwealth. There can be no doubt, therefore, that there must be a growing tendency to adjust the population of the Empire, and it must be adjusted not only by natural increase, but by the artificial methods of migration. There are few people in this country who have devoted more time, attention and skill to problems of migration than our present Chairman, and the only point I want to make is this. It is no use trying to readjust by artificial means the population of the Empire, unless at the same time you are going to readjust the capital and readjust the markets. It seems to me (and may I say—because this is a delicate subject—that I am speaking as an individual and not representing any one except myself?) that if we send our surplus population to Australia, and our surplus capital to the Argentine, and buy our surplus butter from Europe, we can hardly wonder if some of our schemes hang fire economically. Of course, no intelligent person imagines that you can change the direction of the trade of the world with a stroke of the pen, or even that a desire to develop trade within the Empire means confining trade to narrow Imperial channels or carrying on a tariff war with the rest of the world. These things are in any case matters of slow development. Ultimately, demand and supply, quality and price, must be dominant factors in the flow of trade, but I confess to being unrepentant enough to believe that there are endless opportunities of investing capital on sound commercial lines within the Empire; that with the assistance of the public, just as much as with the assistance of any Government, there are endless opportunities of developing British markets for British products, and that the old economic battle between theories of Free Trade and Protection ought no longer to attract the members of different political parties. Once you admit as a truth that problems of migration, production and markets are parallel problems, you can approach every economic theory from a different angle. If by imposing or removing a duty on sultanas, you can find a home for thousands of young Englishmen along the valley of the Murray River, you are no longer a red-hot Tariff Reformer, or a rigid Manchester Free Trader, but you are a level-headed business man who is weighing the advantages and disadvantages of a certain policy in the light of the ultimate advantages or disadvantages which may accrue to the Empire.

Now, this is an aspect of the British Empire Exhibition of which the public must not lose sight. It is a great publicity campaign in which there are three partners: the Dominions and Colonies, ourselves and the British public. The Dominions and Colonies have attractions to offer; it is their business to present these attractions in the most convincing form. It is our business to co-operate in every possible way so that if any Dominion or Colony does not achieve its final object, the blame shall not lie at the door of the Exhibition. And it is the duty of the public to give us all a fair run for our money. They must give a fair run to the Dominions and Colonies, because the amount of Empire produce which can be consumed within the Exhibition is negligible compared with what might be consumed outside. The man who visits the Exhibition and eats a New Zealand lamb chop, half an ounce of Australian butter, a bunch of South African grapes, a Canadian apple, and washes

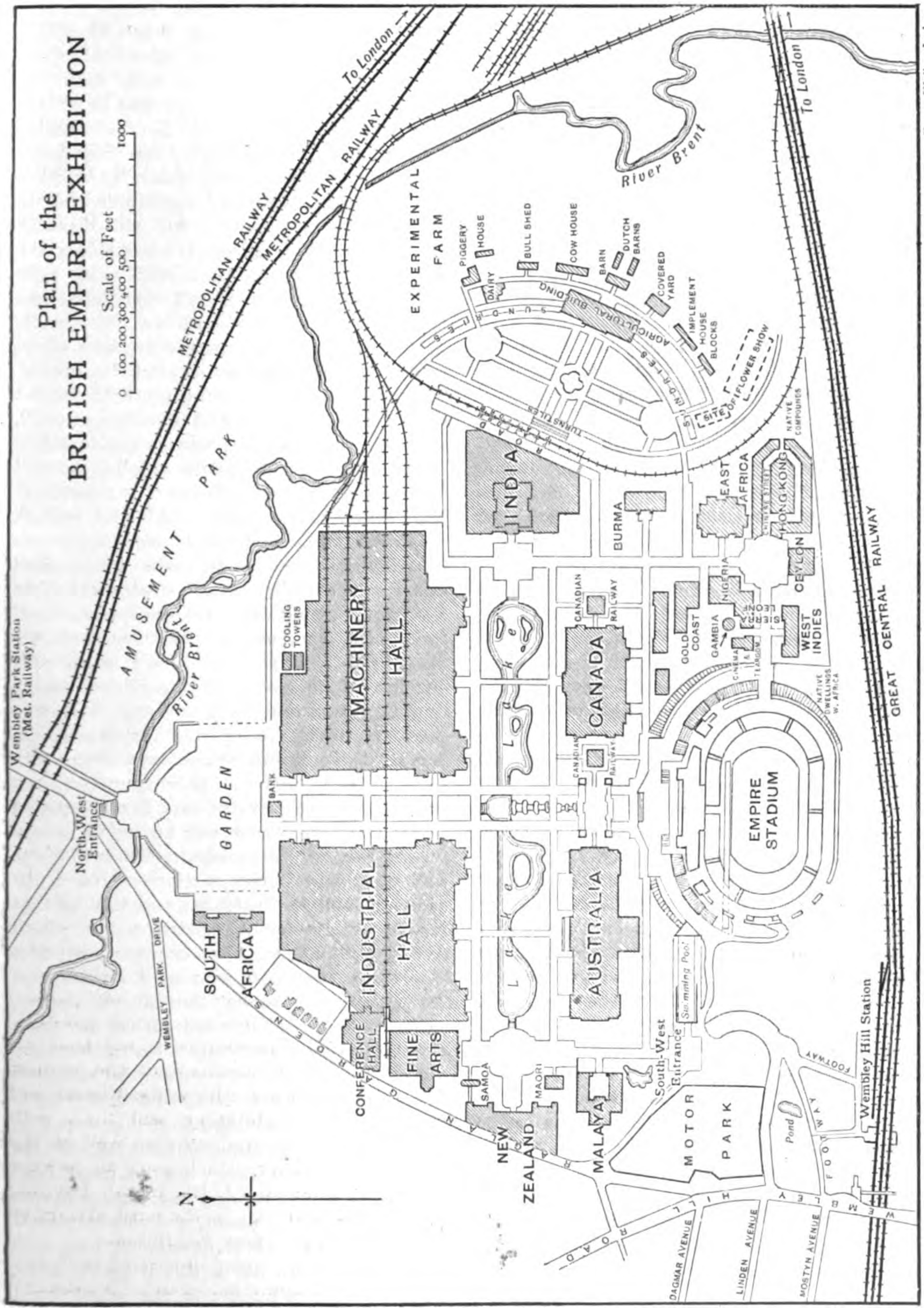
it down with a bottle of Quellthaler or a cup of East African coffee or Ceylon tea, then takes a present home to his wife of an Indian carpet, is not playing the game if he thinks he has fulfilled his duty to the Empire. In common decency, he must give these things a run for their money outside. Personally, I am convinced that if he does so he will continue to purchase these commodities because of their quality and price. I hasten to add that no intelligent person imagines that this means the cessation of all trade relations with the rest of the world. If every Dominion sent every ounce of its exportable butter to this country, there would still be a big market for all the British farmer could produce, and another big market for butter imported from foreign sources. All the Dominions ask is that they should get in on the ground floor and that so long as their supplies last, and from the consumer's point of view they can produce an article which is worth its price, the British consumer should support the family shop.

And the public owes a duty to us. Running an Exhibition is not quite as easy as it might appear. I have no doubt that there are thousands of people outside who think they can do our job better than we are doing it ourselves. I can assure them from the inside that whether that is true or not, it is a very complex job ; it bristles with the most difficult daily problems ; it makes the most exacting demands on our physical strength and our mental energy. We believe we are going to make a tremendous success of it, and because we believe that very sincerely, I think we probably shall make a success of it. But the measure of our success depends on the public. While the Exhibition is being built, we want the people to come and see it ; when the Exhibition is open, we want the whole world there. We want people to talk about the Exhibition and to talk about it helpfully. I have seen a lot of things said about the Stadium. You probably do not know, and I am sure you will like to know, that the Stadium has broken three world's records. It is the largest building in the world—it is the cheapest building in the world—and it has been constructed in the quickest time. Those of you who come in cars to the Final Tie will have an opportunity of parking your cars for that particular day in a building which has a floor space of ten acres. That, and the adjoining building (which also has a floor space of ten acres) are scheduled to be completed on the 11th August, somewhere about eight months before the Exhibition opens. Very shortly we shall launch a number of different schemes which are intended to attract the public to the Exhibition and help to make it a financial success. If the public support us, we shall achieve our ultimate purpose, which is that the Exhibition may be so successful financially that we can hand over Wembley Park and such of the buildings as have been constructed with guarantors' money, as a gift to the nation, an abiding memorial of what the British Empire means and stands for, what it has achieved in five years of peace, and what it may achieve if we adopt and adapt the same spirit of co-operation and loyalty to each other as made the British Empire one of the principal factors in the maintenance of civilisation.

I am now going to ask your attention to a few slides which have been specially prepared from architects' drawings in order to give you some idea of what the Dominion and Colonial Sections will be like. I want to express in particular my thanks to Dominion architects and High Commissioners, and to the various Colonial Group Committees for their courtesy and assistance in the preparation of these slides. They form the most interesting portion of our meeting this afternoon, and without such co-operation I could not have shown them to you. I ought to explain that, as the Empire of India is to form the subject of a separate address here, I have avoided all direct reference to India. This is in fairness to Mr. Kendall, who will, I am sure, give you an extraordinarily interesting account of what India is going to do at the Exhibition. I may, perhaps, be allowed to say that the Empire of India was one of the earliest of the Dominions to throw itself heart and soul into the Exhibition, and that, with the wealth of its resources, as well as the picturesque setting which such an ancient civilisation can afford, the Indian Pavilion cannot fail to be one of the most attractive features of the whole Exhibition.

(Major Belcher then proceeded to throw on the screen a number of slides illustrative of the lay-out of the Exhibition).

Canada is going to occupy a pavilion of 100,000 sq. ft. It is interesting to note


Plan of the
BRITISH EMPIRE EXHIBITION
Scale of Feet
0 100 200 300 400 500 1000
METROPOLITAN RAILWAY
METROPOLITAN RAILWAY
To London
To London
River Brent
River Brent
EXPERIMENTAL FARM
PIGGERY
DAIRY
HOUSE
BULL SHED
COW HOUSE
BARN
DUTCH BARNS
COVERED YARD
IMPLEMENT HOUSE BLOCKS
AGRICULTURAL BUILDING
SITE OF FLOWER SHOW
NATIVE COMPOUNDS
TURNSTILES
AMUSEMENT PARK
Wembley Park Station (Met. Railway)
North-West Entrance
GARDEN
BANK
COOLING TOWERS
MACHINERY HALL
INDIA
BURMA
EAST AFRICA
HONG KONG
CEYLON
NIGERIA
SIERRA LEONE
GAMBIA
GOLD COAST
WEST INDIES
CANADIAN RAILWAY
CANADA
Lake
EMPIRE STADIUM
NATIVE DWELLINGS W. AFRICA
GREAT CENTRAL RAILWAY
SOUTH AFRICA
WEMBLEY PARK DRIVE
INDUSTRIAL HALL
AUSTRALIA
Swimming Pool
South-West Entrance
CONFERENCE HALL
FINE ARTS
SAMOA
MAORI
NEW ZEALAND
MALAYA
MOTOR PARK
Pond
FOOTWAY
Wembley Hill Station
WEMBLEY HILL ROAD
DAGMAR AVENUE
LINDEN AVENUE
MOSTYN AVENUE
N
Emery Walker Ltd. sc.

that this represents a building of the same size as the building which housed the whole of the overseas Empire at the Paris Exhibition of 1900. Within their pavilion they will give some idea of what the primary and secondary resources of Canada are. I am not at liberty to say, even if I knew, what the particular designs of Canada may be in the interior arrangement of their pavilion; I think they want to keep it a secret so that their ideas may not be stolen before the Exhibition opens. I hope, however, they will not forget to show one of the many interesting things which I saw in crossing Canada some few months ago. Prince Edward Island has developed within the last 15 years an extraordinarily interesting industry, and that is the production of fur from foxes in captivity. I believe there is a great future for that. Originally Prince Edward Island started producing black foxes, but the Germans came along and took the Russian red fox fur and dyed it black, and sold it as black fox fur, and killed the market for Prince Edward Island. So the Prince Edward Islanders, instead of continuing dealing with the black fox, went in for the silver fox, the fur of which cannot be imitated, and during my tour through Prince Edward Island I had an opportunity of visiting many of the farms and seeing with my own eyes the way in which the industry was being developed, and seeing also the vast possibilities which it offers to people who care to do it elsewhere. Already silver fox farms are beginning to grow up in other parts of Canada and the United States, and I was very interested to learn (and it has since been confirmed by a letter which I received yesterday), that a silver fox farm is going to be started in Scotland, or has been actually started. The theory is that, wherever foxes exist in their natural wild state, you can also breed foxes in captivity, and that the quality of the fur is very much influenced by the method by which you feed them. If that is true, it is quite possible that silver fox farms may flourish not only in Scotland but in many parts of England where foxes are found to-day.

One could say a great deal about Australia. During my tour through Australia I saw things there which left a great impression on my mind, but perhaps the two things which struck me most were the extraordinary developments which Australia may see in its dried fruit and canned fruit trade, and those in regard to the production of cotton. I want to say a word about dried fruit. There is a river in Australia which is but very little known in this country. It is called the Murray River. It has recently been the subject of an expenditure of about £8,000,000 in locking it. A big irrigation scheme has been undertaken jointly by the New South Wales, Victoria, and South Australian Governments, in conjunction with the Federal Government, with the idea of providing 3,000 miles of navigable river. In the process of providing that 3,000 miles of navigable river, they have also managed to irrigate millions of acres of land, which probably represent some of the best fruit-growing country in the world. This area is rapidly filling up with settlers drawn from Australia and from this country, so much so that even within the last four years the total area of land which is devoted to the cultivation of fruit in Australia has been more than doubled. Indeed, Australia, from the point of view of production has already reached the point when she can produce a great deal more than she can possibly consume, and it is, therefore, of paramount importance that she should find markets for her exportable surplus of raisins, currants, dried fruits, apples, pears and sultanas; and I, who have had the interesting experience of trying these things in competition with supplies drawn from other countries, can assure you that they can meet in competition any other fruit which can be found in any other part of the world. There is one difficulty about the settlement of fruit-growing land in Australia, and that is that nearly every fruit orchard takes about five years before it comes to maturity. Therefore, any man who goes out to grow fruit anywhere along the Murray River, must have enough capital to live for from five to seven years without drawing any money from his orchards, or he must find other sources of income during that period. One thing which will surmount that difficulty is the fact that experts have discovered that just as you can grow as good fruit on the Murray River as you can grow in any other part of the world, so you can grow the best type of long-staple Egyptian cotton; and all along this irrigated area, in between the bushes of the small fruit, and in between the apple trees, the growers are planting Egyptian cotton, and are reaping a large amount of profit from it.

You can get a return from cotton in from five to seven months. Therefore, the settlers, in growing cotton, are not only finding something to support them while their fruit orchards are coming to maturity, but they are helping to solve the great problem which Lancashire has to face to-day—of getting supplies of the best varieties of cotton from within the Empire. Three years ago Queensland produced 1,000,000 lbs. of cotton. The next year she produced about 2,000,000 lbs. Last June when I left, she had already harvested 5,000,000 lbs. This next year, I am told, there will be something like 50,000 acres in Queensland planted with cotton. You can grow cotton in Queensland to the extent of 800 lbs. to the acre, as against an average amount of 479 lbs. in the United States, and cotton growing provides the best of all opportunities for closer group settlement. I know this is a matter of controversy. I can only say that I went all through the Dawson Valley, and I saw men who were handling five, ten and fifteen acres of cotton with no other labour than that which their own families could supply. I met men who found that, by experience, they could get by their own labour themselves a net profit of at least £25 per acre of cotton grown. I do not think there is any likelihood of the price of cotton coming down for many years to come. Nor does a man require a long period of apprenticeship to grow it. I asked the best cotton grower I found in the Dawson Valley where he learned to grow cotton, and he said in a Glasgow carpenter's shop. He had learned to the extent that he was able to grow nearly three-quarters of a ton to the acre, and his daughter, aged 15, held the record in Australia for picking cotton in one day.

New Zealand is very often called the "Britain of the South." I suppose there is no other part of the Empire which presents features of such remarkable interest, not only from the agricultural point of view, but on account of the beauty of its scenery, and in the provision of such things as the best fishing in the world and the best and cheapest deer-stalking in the world. New Zealand will show many interesting things. She produced last year somewhere about £11,000,000 worth of butter. She will also show some very fine flax, which is known as the New Zealand Phormium flax, from which many beautiful Maori robes are made. New Zealand has also many precious stones in great profusion, especially one stone which is commonly associated with China. People always talk in this country about Chinese jade. They do not seem to be aware that jade or green-stone can be found all along the coast of New Zealand, which will show at the Exhibition some jade which is quite equal to any of the jade found in China. In the South Island of New Zealand I had an opportunity of visiting an Institute of exceptional interest at Nelson. Nelson is the centre of the fruit district. A successful merchant who landed in New Zealand with the proverbial barrow some 40 years ago and amassed a large fortune left the bulk of it for the establishment of an Institute of Scientific Research. That Institute was established and has now a staff of quite exceptional merit, drawn partly from New Zealand, partly from Australia and partly from Europe. They have been engaged in one of the most important branches of research work, namely, how to combat some of the diseases and pests which have done, and are doing, so much to ruin certain sections of the fruit industry. Although the Institute has only been in existence for one year, they have found an antidote to the principal pest which has been attacking the apple orchards of the North and South Islands. They have cleared the pest out of the whole of the Nelson district, and they estimate that in a comparatively brief period they will have been able to clear the pest out of the whole of New Zealand. That is a great achievement, and is an achievement which is not only going to be of importance to New Zealand, but which is going to be of corresponding importance to every apple producing country in the world. Whatever New Zealand has done in that way will, I am sure, be the property of the British Empire. I had an opportunity of discussing the question with the particular professor who was responsible for most of the entomological work, and he told me that it would give him the greatest pleasure to come over to the Exhibition and describe the stages of his particular research work which led to this great discovery and to make his discovery the property of any part of the British Empire.

South Africa will have a great deal to show, and I wish I had time to tell you something about it. I have only time to mention two points. It is possible she will bring over some live ostriches in order to persuade people that there is no more

cruelty in removing feathers from an ostrich than there is in removing wool from a sheep. South Africa is one of Australia's principal competitors in fresh and dried fruits, and she has probably given the most convincing example to the rest of the Empire of the value of co-operation applied to fruit marketing. While I was in South Africa I had an opportunity of hearing the debate in the House when the second reading of the Co-operative Bill was under discussion. South Africa has done one thing in regard to co-operation which no other part of the Empire, including this country, has ever done. The attitude of the South African Government on the question of co-operation is this: "We believe that co-operation is a good thing in agriculture. We do not force you farmers to become co-operators, but if you become co-operators we force you to become *loyal* co-operators." It is a very big question, and would take a long time to discuss, but as agricultural co-operation is a matter in which I have been interested very much, I was very glad of the opportunity of reading through that South African Bill and of sending it to one or two friends of mine in England who have been associated with the development of agricultural co-operation in this country, and I suggest that if ever agricultural co-operation is to be the subject of legislation in this country, the Government might do a great deal worse than turn to South Africa for an example of how to achieve it.

The Colonies and Protectorates are arranged in a number of groups. They cannot each of them have separate buildings, because there would not be sufficient room. Each of these groups is under the control of a Group Committee. East Africa will show her developments in cotton and coffee, and will display the fact that she can produce coffee which is just as good as that which comes from any other part of the world.

West Africa has gone in for participation on a very extended scale. West Africa includes Nigeria, the Gold Coast, Sierra Leone and Gambia. One of the principal things she is interested in is palm oil and palm kernels, which together represent about 54 per cent. of the whole of her exports, and a total annual value of nearly £5,000,000 a year. Apart from that, she has a great many wonderful timbers to show, and she is busily engaged in sending a cinematograph operator through West Africa at the present time, who will produce in the cinema theatre in the West African Pavilion complete pictures of what West African life is like.

With regard to British Malaya, 70 per cent. of the rubber of the world comes from British Malaya, and 40 per cent. of the tin of the world comes from there. So that in those two respects alone Malaya will have something to teach us. As a matter of fact, Malaya, in conjunction with Borneo, arranged an Exhibition at Singapore last year, during the time of the Prince of Wales's tour. He visited it, and he was very much impressed with the way in which that exhibition was run. He told me that it was one of the particularly interesting things he had seen in his tour, and hoped that at the British Empire Exhibition the Malay States would have an exhibition somewhat on the same lines. I understand that it is going to be very much on the same lines.

With regard to the Stadium, the turf was laid by that distinguished expert, Mr. Perry. It has only been down three months. It was laid on 5 inches of subsoil. Beneath that there is 12 inches of clinker, and beneath that there is 12 inches of sand. We found that all through the recent heavy rains it drained perfectly. It will be opened on the 28th April on the occasion of the Football Final Tie. There are two stands, which accommodate 12,500 persons each, and there are 10,000 ring seats, and about 40,000 persons can stand along each side. The 35,000 seats for the Final Tie on the 28th April have already been over applied for.

(Major Belcher concluded his lecture by showing photographs of the interior of the Stadium, and of the interior of the machinery hall, 60 per cent. of which, he mentioned, had already been taken by the British Electrical Association and the British Engineering Association, and it was anticipated that long before the building was complete 100 per cent. of the space would be occupied.)

DISCUSSION.

THE CHAIRMAN (the Rt. Hon. L. S. Amery, M.P.), thought the audience would agree that they had listened to a very interesting lecture, which had made them realise something of the importance of the British Empire Exhibition, and more particularly of the Dominions' and Colonies' share in that Exhibition. Major Belcher had made it clear that it would be something more than an ordinary Exhibition. It was to be not merely a record of what the Empire had achieved and could do in the way of material

development, but it was to be an object-lesson to every part of the Empire of what could be done by mutual co-operation. Personally, he thought the only way out of the difficulties which the war had left behind for the Empire was the way of mutual co-operation in Empire development. Major Belcher had very rightly said that that development demanded the proper co-operation and mutual adjustment of three things, namely, population, capital and markets. Men, Money and Markets—those three M's were the key to the whole problem of Empire and to the whole problem of our future security. In different degrees we each stood in need of them. All the Dominions needed men, money and markets. In so far as they needed men—and in that word he included women and children—they could get the best from the United Kingdom. In so far as they needed money, they could still, in spite of everything else, get the cheapest in the London market. In so far as they needed a market, they had the best consuming market in the United Kingdom. Taking, on the other hand, the United Kingdom's point of view, we could never have too many men in the sense of fellow-citizens, but undoubtedly at the present time we had more population in this country than the present industrial position—the labour market position in this country—could support. By Empire development the industrial problem here could be eased without losing our fellow-citizens from the companionship and comradeship of the British Empire. We still had more money than we needed for the development of the United Kingdom, but we had not enough to burn or scatter all over the world. We should do well to concentrate our surplus capital upon the development of the Empire. Markets we needed above all things, and the problem of markets since the war had become in an ever-increasing degree an acute one. Many markets on which we used to rely were no longer what they were. They would not be what they were for many years to come, and their recovery was in a very large measure beyond our control. The development of the Empire market was something that, with the co-operation of the Dominions, was within our control. There was a certainty. In respect of any other markets outside, there was only uncertainty and doubt. So there was a clear line of policy before us. It was not a policy of exclusion. We did not want to cease to trade with the outside world, nor did we want the Dominions and Colonies to cease trading with the outside world. What we did want to do was to concentrate our minds and to give our first thoughts to the development of the richest and most certain vein of trade—trade within the Empire and the development of the Empire. That was what he would call, using the words in their widest sense, a policy of Imperial preference. If our men left these shores, let us encourage them to go to the British Empire rather than to any foreign country. Let any part of the Empire, if they needed immigrants, encourage people from the old country—the best stock in the world—rather than people from any other part of the world. The same with capital. The same with trade. The same with the whole problem of development. Let us give to every part of the Empire, wherever we were, the chance of coming in on the ground floor. That, to his mind, summed up in a sentence or two the gist of what Major Belcher had been trying to impress upon them that evening, and what he believed and hoped would be really impressed upon the minds of this country and of the Empire by that great Exhibition, of which Major Belcher had spoken—a great object-lesson to the Empire and to the world.

THE AGENT-GENERAL FOR VICTORIA, Mr. John M'Whae, in proposing a hearty vote of thanks to Major Belcher, said the Dominions and Colonies represented an outlet for this country's men and money. There were millions of men too many in the United Kingdom. The Dominions and Colonies were waiting for them.

THE AGENT-GENERAL FOR SOUTH AUSTRALIA, the Hon. Sir Edward Lucas, in seconding the motion, said he did not know what the views of the lecturer had been before he went on his world tour, but there could be no doubt that he was now a confirmed Imperialist. Major Belcher, he felt sure, was more satisfied to-day than he had ever been, that the Empire could be made self-contained if the different Dominions and Colonies and the Mother Country only co-operated with each other. While Mr. Amery had been Chairman of the Overseas Settlement Committee, he had clearly and emphatically urged that the doctrine for the future was not emigration but simply a better adjustment of the man power of the Empire within the Empire, and had said that the best thing to be done in this country was to lay out plans for the cultivation of the family estate as it was found in other parts of the world, and not merely to draft out of this country the surplus population. He (the speaker) thought that the gentlemen who had recently spoken in the House of Commons on the question of emigration did not represent anything like the consensus of opinion in this country. Any thoughtful man, when he remembered that the natural increase of population in Great Britain was 500,000 a year and that within another ten years there would be another 5,000,000 people here, would agree that it was altogether too many for this small patch of land to support as it ought to be supported. Yet in various parts of the Empire were great undeveloped resources, the fringe of some of which had not yet been

touched. Those were the places to send the surplus population of this country to—not to places under foreign flags. There was no doubt as to what would have been the result to this country if the men who had drifted across the Atlantic within the past half century had gone instead to various parts of the Empire, and had settled under the Union Jack and been available when the great war broke out. And might he say, with all due respect to the patriotism of the people of this country, that in the matter of loyalty the people of the Dominions and Colonies excelled the loyalty of the people here? When the Prime Minister sent his message to Mr. Hughes, the Government offices were literally besieged by men applying to volunteer to come to help this country. Major Belcher had viewed the question of the Empire Exhibition, not merely from the immediate results which it would produce, but from the standpoint that it would bring home to the people of this country as they had never realised before, the enormous possibilities of this great family estate of ours which was scattered about all over the world. The one thing he (the speaker) wanted to see—and he hoped it would be realised—was that after the Exhibition had been held, the people of this country would make up their minds to buy the Colonies' and Dominions' products more loyally than they had done in the past. The Dominions wanted not only the people of this country, but the Government, to realise that they could get all required for the British Army and Navy from their own Dominions without having to go outside. In that connexion he might mention that only just recently the War Office had let a contract for the supply of meat for the next six months to a foreigner. The Dominions did not approve of that kind of practice, and he hoped it would cease.

Sir Stephen Collins, ex M.P. for the Kennington division, said he could not help quoting the words which the Chancellor of the Exchequer had used a day or two previously when trying to inspire Great Britain and other countries to get over the difficulties of the day. The Chancellor had said that what was required was faith, hope, love and work. Major Belcher had shown that he possessed all these. Certainly no man could have given an address such as he had delivered that afternoon if he had not love of the work. The occasion was of great interest to himself because just before the war he had had the privilege, with Mr Amery and other Parliamentary colleagues, of visiting the Dominions when he saw much to verify what Major Belcher had told them that afternoon. Perhaps he might be excused if he referred to one little incident which occurred during the tour. In Australia the party visited a cadet camp where young men were trained for the army. Those young men went through several of their performances with great agility. In connexion with one of the items of the programme there was a temporary fence about 10 feet high, and many of the cadets had great difficulty in getting over the top. To the party's great surprise, however, Mr. Amery went forward and mounted that fence with the agility, he would almost say, of a monkey, and went over the top apparently with the utmost ease.

The motion was carried unanimously.

Major Belcher, in reply, said he would like to take the opportunity of expressing his very great thanks to Mr. Amery for presiding that afternoon. Mr. Amery would do everything he could for any subject in connexion with the Empire. Although Mr. Amery and himself were very old friends, he realised that to call on an old friend for a favour was one thing, but when that friend happened to be First Lord of the Admiralty and immersed in all sorts of Government problems, it was another thing to expect him to spend the time necessary in presiding over a Meeting; he was extremely grateful to Mr. Amery for having done so that afternoon.

The Agent General for Tasmania, Mr. A. H. Ashbolt, on behalf of the Council, thanked Mr. Amery for taking the chair. Mr. Amery was an example of the old saying that it was only a busy man who had any spare time. The work which Mr. Amery had given to Empire matters and the settlement of the surplus population of Great Britain overseas was one which would go down to posterity as an illustration of the work of an Englishman. It was only an Englishman who had been through the Empire and who knew what the Empire was, who could have the faith, hope and courage to do what Mr. Amery had done.

The Chairman, in returning thanks, said they all tried in their varions ways to work for the things which interested them. Sometimes it was a small incident which got remembered and by which they were thought of. His old friend Sir Stephen Collins must have listened to many speeches of his, which probably had made no impression on his mind at all, but when Sir Stephen had seen him scramble over a 10 foot fence, that seemed to have made an ineffaceable impression!

NOTES ON BOOKS.

X-Rays. By G. W. C. Kaye, O.B.E., M.A., D.Sc., F.Inst.P. Fourth edition. London: Longmans, Green, and Co. 16s. net.

Great advances have been made in the study of X-rays since the first edition of this text book appeared in 1914, and among those responsible for these advances no one is more prominent than Major Kaye, whose course of

Cantor Lectures on the subject in 1921 will be familiar to most readers of the *Journal*. Another work of his, "The Practical Application of X-rays," was reviewed in these columns in November last. The present book treats more fully of the theoretical side of the subject, although such aspects as the use of X-Rays in medicine and surgery, and for detecting flaws in metals, timber, etc. are not forgotten.

An interesting point discussed by Major Kaye is the length of exposure required in taking X-ray photographs. In contrast with the prolonged exposures necessary in the early days snapshots can now be taken through any part of the body, and almost any of the moving organs can be radiographed. Thus Figure 78 shows a radiograph of a thorax in which the exposure was only one-hundredth of a second, and a radiograph has even been taken of a bullet leaving the muzzle of a revolver. But if the ideal of X-Ray workers is to be realised viz., "to make the taking of an X-ray photograph as easy and silent as that of light," a great deal has yet to be done. The probable lines on which these developments will take place are indicated by Major Kaye.

We are extremely glad to welcome the fourth edition of this admirable text-book, and we hope it will continue to be revised from time to time as advances in the science and art of radiography may render such revision desirable.

THE NORTHWARD COURSE OF EMPIRE. By Vilhjalmur Stefannson, London: George G. Harrap and Co., Ltd. 7*s.* 6*d.* net.

This is a book of extraordinary interest, challenging as it does, all our pre-conceived notions if the Frozen North, and throwing a fresh flood of light upon the actual conditions of the Arctic Zone. How does the man-in-the-street visualise Northern Canada? Certainly not as a vast pasture. Yet such it is. We have here from one and a half to two million square miles of prairie land, equal to half the area of the United States, while in Northern Eurasia the area is estimated at from four to six million square miles. Even in winter much of this is only thinly covered with snow, while for four or five months you have green prairies and flowery meadows. In some parts of "the Frozen North" the shade temperature is summer is 100°F., and with the continuous daylight plant-growth is very rapid, so that such cereals as rye and barley, and many garden vegetables can be cultivated with success.

It is not, however, any part of Mr. Stefansson's policy to develop the Northern lands on the lines with which most of us are familiar. "It seems to me," he writes, "that one of the greatest industrial reforms of our time will come when the food producers of the world . . . . . cease their profitless endeavours to force the hand of nature, and begin to adapt themselves to conditions by producing in each locality that food product which experiments shall show to be of those available the most nearly native." Sheep and cattle *may* perhaps be reared successfully in Arctic regions, but the cost of feeding and sheltering them in the winter would certainly do away with any profits. Reindeer, on the other hand, can fend for themselves in almost any weather. Alaska is already carrying on a considerable reindeer industry; in 1903 it had about 6,000 domesticated reindeer; today it has 200,000; and in another twenty years its annual output, according to official estimates, should be a million and a quarter carcasses.

Mr. Stefansson estimates that Canada should ultimately be able to supply annually from ten to thirteen million carcases, "the equivalent of twenty-five million carcases of sheep, which is more than the total product of Canada to-day in all forms of domestic meats."

Another animal which may be destined to play an important part in augmenting the world's supply of food is the ovibos—a beast about the size of Highland cattle, with a thick coating of mixed wool and hair. Its flesh is, if anything, superior to beef, and the fleece has many valuable qualities. This animal moves about very slowly when grazing, and apparently there would be little trouble in keeping it within bounds. There seems to be no reason why the ovibos should not be reared as successfully as the reindeer.

Most people accustomed to a temperate zone would shrink from the idea of passing their lives within the Arctic Circle: but a perusal of Mr. Stefansson's chapter, "The Livable North," might do something to remove their prejudices. To keep warm in a temperature fifty degrees below zero is mainly a matter of proper dressing and food. To keep cool in a shade temperature of a hundred degrees is for many people an impossibility. The Polar zones are practically germ-free, and their inhabitants enjoy exuberant health, whereas if they are transplanted to warmer climates they almost invariably succumb to disease. Nor is it only those from temperate climates who can grow accustomed to the Far North. Numerous cases are mentioned of negroes and men from tropical countries who lived healthily and happily in the Arctic: in particular, Mr. Stefansson quotes the case of his friend, Jim Fiji, a native of Samoa, who, after spending his active life in the North, voluntarily retired to end his days on one of the most northern points of Canada!

COTTON GROWING MACHINERY.

By G. A. LOWRY.

In view of the extremely high price of cotton and the likelihood that it can never return to its former low level—because of the boll weevil and the shortage and growing

inefficiency of negro labour in the southern states—it might be well for those endeavouring to raise cotton in the Soudan and other British Possessions to know some of the mechanical difficulties met in an endeavour to lighten the labour costs in cotton production.

Cotton seeds are planted in a continuous row in furrows about three feet apart. It is not possible to make the ridges of these furrows of even height nor, as a rule, do all the seeds germinate, so the ridges present a rather ragged surface with a somewhat broken line of vegetation.

The usual method in hoeing cotton is first to cut out the surplus plants when they are about two inches above the ground, leaving one plant, and if possible the sturdiest, every six inches; at the same time hoeing out carefully all the weeds on and between the furrows. This must be done thoroughly as the weeds grow faster than the cotton and would, in time, over-run it. A few weeks later when the cotton has more growth the plants are cut out to twelve inches apart and still later to eighteen inches apart.

All the mechanical attempts to do this automatically have been along the same line. The machines were made to scoop out a six-inch section of the furrow every alternate six inches; but as the machines could not distinguish between bare spots and spots where seeds had germinated, and were as likely to take the latter as the former, they met with little success and they were useless for removing weeds.

A good hand hoes three quarters of an acre per day.

When the cotton plant attains its growth, the longest and heaviest branches and those having the most bolls, are those close to the ground—frequently resting on the ground. The plant ripens gradually from the bottom to the top in a period of about three months; the bottom crop being ready to pick while the top crop is still in bloom. There are usually three pickings; the bottom crop, the middle crop and the top crop. If frost comes early in the season, the latter crop is generally lost. If the bottom and middle crops are not picked when the bolls open, the rains and wind dislodge much of the fibre and it becomes either lost or earth stained.

Mechanism to do the picking economically must be able to make trips through the plants without injury to the bloom and the immature bolls on other parts of the plant; and must be able to pick the cotton from the branches on or close to the ground.

Several millions have been spent in efforts to produce cotton pickers, but there are none in regular use. The three principal types are:—1. The suction machine. 2. The rat-tail file machine. 3. The card cloth belt machine.

Because a great many of the bolls have broken stems and come off easily, it was necessary to make the suction tubes of sufficient diameter to take a wholly opened boll—or about four inches in diameter—making them so unwieldy that they fell much below the capacity of a good hand picker.

The second type had a large number of rat tail like fingers which penetrated almost every part of the plant, revolving rapidly as they went in, winding around them all the fibres with which they came in contact. They were then withdrawn into a hopper and revolved in an opposite direction to release the cotton wound around them.

I have seen these machines pick a considerable amount of cotton on rows where there were no low branches and where the whole plant had been allowed to ripen.

This machine has above three thousand cut gears and pinions and is quite costly.

The third type has a number of narrow card cloth belts with overlapping teeth mounted on counter balanced dirigible arms and manipulated by boys seated on the machines; each boy with an arm in each hand and using his feet to lift the ground branches so he can pick the bolls underneath and the cotton on the ground which had been washed out by the rains.

This machine greatly increased the capacity of the pickers and appeared to have a promising future until it was discovered that there was no profit to the Planters in a cotton picker; their argument being that they had to keep and support a sufficient number of negroes on the plantation all winter and spring to do the hoeing before the weeds came up and choked the plants: that this work by no means allowed the negroes to pay up their indebtedness, and they had to let them pick cotton to get even; that in reality their cotton picking cost them nothing and there was no saving until mechanism was devised to do the hoeing as well.

As the two items of labour, viz., hoeing and picking, are the material costs in the

production of cotton, much thought is still being given to their partial elimination; but I think all inventors who, like myself, have had extensive field experience, have reached the conclusion that semi-automatic machines are the only kind likely to be successful.

Hand picking has degenerated from 400lbs. per day, per hand (before abolition) to very little above 75lbs. per day for the average (at present); so a mechanism which will even bring it up to the original amount would be a great gain providing it will do the same thing for the hoeing.

THE CHINESE JADE INDUSTRY.

The name jade is given to two kinds of hard stone—nephrite and jadeite. The nephrite, a silicate of calcium and magnesium, varies in colour according to the amount of iron contained, being white, blue, green, yellow, red, and black. The jadeite, a silicate of aluminum and sodium, is more vivid and translucent than the nephrite.

The first jade mines known in China were located in Shensi and Honan, but later discoveries were made in Hunan and Kansu. After the eleventh century, however, China's supply became exhausted, since which time most of the stone used has been imported from Burma and Turkestan, the latter country furnishing practically all the white jade used in China.

According to the official United States "Commerce Reports," Canton, Peking, Soochow and Shanghai are the largest producers of carved jade, with Canton far in the lead. Peking ranks second, but the industry in the other two cities, as well as practically all the coast ports, employs but a few men. Chinese dealers and carvers generally refuse to handle more than one colour of jade. Those in Peking, Soochow and Shanghai confine themselves almost exclusively to the white, used in making bracelets for men, belt buckles, vases, incense burners, and other large objects, while Canton has been for centuries the centre of the green-jade industry and sets of the styles for ornaments made from it.

There are no jade nanufacturers in Canton in the real sense of the word. Anyone may purchase the stone and send it to contractors to be cut into articles by skilled workmen. A rigid system of weighing and inspection prevents any stealing by either contractors or workmen during the process.

The contractor owns the shop and tools, solicits orders, and hires the jade workers, paying the latter by the piece and providing food and lodging. The contractor's payment is usually divided so that he receives 60 per cent. and the workmen 40 per cent.

There are about 10,000 workmen engaged in the jade industry in Canton, who are organised into four trade groups or unions, as follows: Cutters, bracelet makers, plain carvers and ornate carvers. Years of experience have produced highly specialised workers in the last-mentioned group.

The green-jade importing business in Canton is handled by seven Cantonese firms, which buy direct from Burma. Members of these firms are stationed in Burma during the buying season, which occurs about May, when the stone is quarried. Once a year, usually at the beginning, the jade market is open for selling the imported stone, at which time the entire year's supply is to be disposed of. On the day before the sale, the stones to be offered are exhibited, each piece bearing a number and cut so that the interior colour is exposed. Prospective customers visit the exhibitions and make notes of the pieces they wish to purchase.

Secret bids are used in the sale. The auctioneer stands in the middle of the floor, wearing a coat with extra long and wide sleeves. When the number of the piece to be sold is announced, the buyers rush to the auctioneer, grasp his hand under the sleeve, and communicate their bids by means of standardised grips, a common method everywhere in China. These auctioneers have remarkable memories, taking bids from two buyers at the same time, and remembering all bids and bidders. Since he declares a piece sold as soon as a sufficiently high bid has been made, there is a wild rushing when a particularly fine piece is announced. However, this bid accepted by the auctioneer is subject to the approval of the importing house, which may order the piece to be re-sold.

There are two jade exchanges in Canton, and both are open every morning. One handles goods of the better quality, and the other inferior products. Each seller hires a booth in which to display his wares. The system of secret selling is also employed at these exchanges, and it is useless for any but experienced buyers to attempt to make purchases. Tourists purchase generally from the 40 or more jade stores in Canton, some of which operate on the one price basis. Most of them, however, "squeeze" as much as possible from every customer.

THE COCO-NUT WEEVIL

The Department of Agriculture of Ceylon has recently published three "leaflets" regarding the insect pest of the coco-nut palm. The first two of these deal with the coco-nut caterpillar and Black Beetle respectively, while a third treats of the Red Weevil (*rhyncophorus ferrugineus*). This pest is considered by Mr. J. C. Hutson, the Government entomologist and the writer of the leaflet, to be the most important pest of the three in Ceylon, since it is prevalent on all coco-nut areas, and is capable

in the larval stage, of killing young, and seriously injuring, older palms.

The pest does practically no damage to palms when in the weevil or adult stage, beyond making small holes or punctures with its proboscis in any wound or soft spot, partly for feeding and partly for laying eggs. The actual agents of destruction are the larvæ which hatch from these eggs and tunnel about inside the palm, eventually eating out a fairly large cavity inside the trunk or crown, damage which is often not detected until it is too late to save the palm. Quite young palms, four or five years old, are quickly riddled and killed off by an attack of weevil grubs, while injury to palms a few years older is often fatal, inasmuch they may be attacked anywhere from the base to the crown. Injury to the crown is almost invariably fatal unless detected early, and results in the withering and collapse of the young central leaves. When the base or trunk is attacked the injury may sometimes be detected by the oozing of a brownish liquid, or by the escape of small pieces of chewed fibre from a small hole. Old palms may sometimes be attacked in the crown, but rarely at the trunk or base on account of the hardness of the tissues.

The red weevil is one of the largest of the proboscis-bearing beetles. It is usually about 1½ inches long including the proboscis, and is generally of a reddish-brown colour, with black marking behind the head, but varies considerably in size, colour and marking. In the adult stage the weevils do very little feeding on the palms, but can live for two or three months after emerging from the cocoon. Injured or diseased palms quickly attract them, and experiments recently conducted in the Dutch East Indies indicate that they can detect favourable breeding places at a distance of 1,000 yards.

The red weevil is small and more slender than the black beetle, and is reddish-brown in colour, with a long slender proboscis projecting forward and downward from the front part of the head. The black beetle is dark brown to blackish in colour, with a horn curving upwards and back wards from the top of the head. The weevil itself does practically no injury to the palm, but the beetle damages palms by boring into the crown in order to feed on the sap.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, APRIL 23 .. British Architects, Royal Institute of, 9, Conduit Street, W., 8 p.m. Mr. W. G. Newton, "The Literature of Architecture."

British Academy, King's College, Strand, W.C., 5 p.m. Prof. A. Pollard, "The Foundations of Shakespeare's Text."

Victoria Institute, Central Buildings, Westminster, S.W., 4.30 p.m. Dr. D. Anderson-Berry, "Occultism at the Bar of Philosophy and Religion."

Geographical Society, 135 New Bond Street, W., 8.30 p.m. Mr. L. M. D. Buxton, "Inner Mongolia."

Mechanical Engineers, Institution of (Graduates Section), Mr. S. H. G. Warne, "Recent Steam-Wagon Progress and a Suggested Design."

Brewing, Institute of, 30, Russell Square, W.C., 8 p.m. Mr. H. M. Lancaster, "Moisture in Malt."

Faraday Society, at the Chemical Society, Burlington House, Piccadilly, W., 8 p.m. 1, Messrs. J. H. Shaxby and J. C. Evans, "On the Properties of Powders—The Variation of Pressure with Depth in Columns of Powders." 2, Mr. E. E. Walker, "The Properties of Powders." Part VI., "The Compressility of Powders"; Part VII., "The Distribution of Densities in Columns of Compressed Powder." 3, Mr. E. K. Rideal, "On the Rate of Hydrogenation of Cinnamic and Phenylpropiolic Acids." 4, Mr. A. Taffel, "The Temperature of Maximum Density of Aqueous Solutions." 5, Mr. Leonard Anderson, "Note on the Coagulation of Milk by Acid."

TUESDAY, APRIL 24 .. Illuminating Engineering Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 8 p.m.

Royal Institution, Albemarle Street, W., 3 p.m. Sir Arthur Keith, "The Machinery of Human Evolution." (Lecture III.)

Colonial Institute, Hotel Victoria, Northumberland Avenue, W.C., 4 p.m. Mr. J. H. P. Murray, "Modern Papua."

Photographic Society, 35, Russell Square, W.C., 7 p.m.

WEDNESDAY, APRIL 25 .. Literature, Royal Society of, 2, Bloomsbury Square, W.C., 5 p.m.

THURSDAY, APRIL 26 .. Royal Society, Burlington House, Piccadilly, W., 4.30 p.m.

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C., 6 p.m. Messrs. L. Breach and H. Midgley, "The Drive of Power Station Auxiliaries."

Mechanical Engineers, Institution of (Midland Branch), The University, Birmingham, 7.30 p.m. Dr. F. W. Lanchester, "Epicyclic Gears."

Child Study Society, 90, Buckingham Palace Road, S.W., 6 p.m. Dr. W. G. Sleight, "Children's Taste in Pictures."

Royal Institution, Albemarle Street, W., 3 p.m. Prof. J. T. MacGregor-Morris, "Modern Electric Lamps." (Lecture I.)

FRIDAY, APRIL 27 .. Royal Institution, Albemarle Street, W., 9 p.m. Mr. C. V. Boys, "Measurement of the Heating Value of Gas."

Photographic Society, 35, Russell Square, W.C., 8 p.m. Mr. A. Watkins, "Early British Trackways."

Sanitary Institute, Guildford. Sir Arthur Newsholme, "Things that Matter in Public Health."

Physical Society, at the Imperial College of Science, South Kensington, S.W., 5 p.m.

Engineers, Junior Institution of, 39, Victoria Street, S.W., 7.30 p.m. Mr. J. Fearn, "Stock Control."

Royal Dublin Society, Leinster House, Dublin, 4.15 p.m. 1, Mr. A. E. Clark, "Evidence of Displacement of Carboniferous Strata in County Sligo." 2, Dr. E. J. Sheehy, "The Effect of Feeding on the Fat Content of Milk." 3, Dr. T. J. Nolan, and Mr. H. J. Clapham, "The Utilisation of Monomethylaniline in the production of Tetryl."

SATURDAY, APRIL 28 .. Royal Institution, Albemarle Street, W., 3 p.m. Dr. L. L. B. Williams, "The Physical and Physiological Foundations of Character." (Lecture I.)

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICES.

NEXT WEEK.

MONDAY, APRIL 30th, at 8 p.m. (Howard Lecture). STANLEY S. COOK, B.A., M.I.N.A., M.I.M. (Parsons Marine Turbine Co.), "The Development of the Steam Turbine."

POSTPONEMENT OF ORDINARY MEETING.

Owing to the sudden and serious illness of MR. MAURICE DRAKE, it has been found necessary to postpone the reading of his paper, "The Fourteenth Century Revolution in Glass Painting." Consequently there will be no Ordinary Meeting on Wednesday, May 2nd, as previously announced.

EIGHTEENTH ORDINARY MEETING.

WEDNESDAY, APRIL 18th, 1923; MR. ALDERMAN W. PHENÉ NEAL, late Chairman of the Cattle Markets Committee of the Corporation of the City of London, in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Cadman, Sir John, K.C.M.G., D.Sc., Pres.Inst. M.E., London.
Hanson, Joseph, J.P., Rochdale.
Parsons, Joseph Greeley, M.D., S. Dakota, U.S.A.
Saran, Sahu Brijpal, B.A., United Provinces, India.

The following candidates were duly elected Fellows of the Society:—

Campbell, C. A., Tampico, Mexico.
Crowder, Martin Henry, Bombay, India.
Crowder, William Benjamin, London.
Hanslux, M., Delhi, India.
Neill, Miss Alma J., A.M., Ph.D., Oklahoma, U.S.A.
Ohlson, Olof, West Newton, Massachusetts, U.S.A.
Simpson, John Henry, Calcutta, India, and London.

A paper on "Modern Abattoir Practice and Methods of Slaughtering" was read by MR. HAL WILLIAMS, M.I.Mech.E., M.I.E.E., M.I.Struct.E.

The paper and discussion will be published in a subsequent number of the *Journal*.

DOMINIONS AND COLONIES AND INDIAN SECTIONS.

FRIDAY, APRIL 20th, 1923; LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, in the Chair.

A paper, "A Review of the Base Metal Industry, with Special Reference to the Resources of the Empire," was read by SIR RICHARD A. S. REDMAYNE, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S.

The paper and discussion will be published in a subsequent number of the *Journal*.

CANTOR LECTURE.

On MONDAY EVENING, APRIL 30th, MR. E. KILBURN SCOTT, Assoc.M.Inst.C.E., M.I.E.E., delivered the third and final lecture of his course on "Nitrates from Air."

On the motion of the Chairman, SIR CHARLES BEDFORD, LL.D., D.Sc., a vote of thanks was accorded to MR. KILBURN SCOTT for his interesting course.

The Lectures will be published in the *Journal* during the Summer Recess.

PROCEEDINGS OF THE SOCIETY.

THIRTEENTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 28th, 1923.

THE HON. SIR CHARLES A. PARSONS, K.C.B., LL.D., D.Sc., F.R.S., in the Chair.

The following paper was read:—

HEAT RESISTING GLASSES.

By PROF. W. E. S. TURNER, O.B.E., D.Sc., F.Inst.P.

Power to resist sudden changes of temperature is not a property which is normally associated with glass. The occasional cracking of thick tumblers when hot liquids are poured into them and of lamp chimneys when the flame momentarily touches them, serve to remind one that

ordinary glass is not an ideal heat resister.

The first and probably most widely understood cause of this tendency to fracture on heating is the low thermal conductivity, so that, on heating the glass object, the slow flow of heat across its walls results in great tension on the colder layers not exposed to the source of heat, due to differential expansion.

But relative conductivity for heat alone does not entirely account for the fracture. The thermal conductivity of metals is very good, but even large castings of metal often need annealing to remove stresses due to rapid cooling, whilst large ingots may even develop cracks.

If a thick vessel of iron and one of glass, both containing water, were placed on a fire, the former would give service as a boiler, the latter would fracture. The iron possesses the advantage of much greater conductivity, but on the other hand, the glass has a considerably smaller thermal expansion and larger specific heat, both of which should do something to redress the balance between the glass and the iron. The latter, however, has far and away the greater tensile strength, and it is to their mechanical strength, as well as to their heat conductivity, that metals owe their superiority as heat resisters.

Winkelmann and Schott introduced the term "thermal endurance" to denote the power of a glass to withstand thermal shock. In practice the thermal endurance may be determined by heating equal lengths of glass rods of the same diameter in an electric tube furnace to varying temperatures and determining the comparative tendency to fracture when dropped suddenly into cold water. Flasks and beakers are filled with molten paraffin wax heated to varying temperatures between 150° and 250° C and plunged into water at 20° C. Ordinary heavy bottles used for beverages may be filled with water, heated in a water bath to 70° to 85° C., and then cooled in water at 20° C. The Home Office test which miners' lamp glasses must pass is immersion in boiling water for 20 minutes followed by chilling in water at 60 to 65° F.

The formula which was deduced to represent the relationship of the thermal endurance, F, to the other properties was

$$F = \frac{T}{E\alpha}\sqrt{\frac{K}{Dc}}$$

where T is the tensile strength; E, Young's modulus of elasticity; α, the linear coefficient of thermal expansion; K, the conductivity for heat; D, the density; and c, the specific heat.

It is to be noted that the properties which directly affect the thermal endurance are the tensile strength, the elasticity and the co-efficient of expansion, the remaining three properties producing an effect proportionate either directly or inversely to their square roots.

In practice, so far, the attempts which have been made to improve the heat resisting power of glass have been either in the direction of increasing the mechanical strength or of diminishing the co-efficient of expansion.

The earlier attempts were designed to improve the mechanical strength by processes of hardening them; thus, we have de la Bastie's method of hardening glass, an attempt which created something of a sensation at the date of its publication about 1874. A description of this process was given to the Society by Mr. P. F. Nursey(1) in 1875. The glass to be treated was heated up to the stage of softening and then allowed to slide from the heating muffle into a covered bath of hot oil made up of a mixture of oils, wax, tallow, resin etc. Watch glasses, plates, dishes and plain and coloured sheet glass, were stated to be capable of such treatment and a glass saucer so tempered could be used for boiling water over a brisk fire and be quickly removed without being affected. The sheet glass also became so tough that small metal weights could be dropped from a considerable height on to it without causing fracture.

This mode of treatment undoubtedly induced greater mechanical strength, and, therefore, also, resistance to thermal shock, by the fact that the outer layers were in compression whilst the inner were in tension. On heating, the stresses were to a certain degree relieved.

According to Pilati (2) Bastie's glass had the composition SiO_2, 63.8, CaO 10, Al_2O_3 2, alkaline oxides 17, MgO, Fe_2O_3, etc., 3, so that the glass was a common soda-lime glass.

A great future was predicted for the process which was to revolutionise the application of glass throughout the world,

(1) J. Soc. Arts, 1875, xxiii, 631.
(2) Glashütte, 1875, 10.

but it is a very striking fact that, although serious experiments were made in this country to apply the new idea to various articles of glassware, no commercial success was attained then and various attempts along similar lines in the years which have followed have all achieved no tangible success.

Of the various other systems of toughening glass, probably that of Siemens is best known by repute, the process apparently being to subject the articles to mechanical pressure inside moulds of special design either of metal or fireclay. So far as the author is aware, there are no lucid accounts of this process which the ordinary reader has access to, the patent descriptions being rather vague and of doubtful accuracy.

The most successful method in which mechanical strength was made to resist thermal shock was that of O. Schott, described in 1892. He showed that under certain conditions glasses of different co-efficient of expansion could be united when gathered on the blowpipe in successive layers. When a glass article was made of which the inner part had a lower co-efficient of expansion than the outer, and the article so cooled in the air that the outer layer was rapidly chilled and thus exerted a compressive force, it then resembled hardened glass. We thus get an arrangement of layers of which the inner parts are in compression while the interior or middle layers are in tension. A second arrangement was to have the layer of bigger coefficient on the inside and a thin layer of low coefficient outside. Schott had glasses of this kind made up into flasks and cylinders which could be heated to a temperature of more than 180° C. and did not fracture when cold water was sprayed on to them. Gauge glasses could be plunged into water without fracture after being heated in oil to 200 to 230° C.

This method of hardening by making compound glass has had actual use for boiler gauge tubes and for a number of years they were placed on the market by Schott and Gen, under names such as "Robax," "Durax," etc. I understand that experiments on compound glasses, double and triple, were carried out for some years by a British firm with striking results. Such glasses, being in a highly stressed condition when cold, involve an element of risk and have frequently undergone spontaneous shattering in storage. For this reason they have not found favour with British glass manufacturers, and the Jena products appear to have had only a limited demand.

The second method, namely, that of controlling the co-efficient of expansion, was adopted at a later stage, and has been the basis of many successful developments in recent years. The German Reichanstalt(3) has proposed that the suitability of a glass for protecting an illuminating flame shall be judged on the basis of its co-efficient of expansion. It proposed that in the first class of high resistant glasses, the upper limit for linear expansion should be 35×10^{-7}; for good glasses in the second class, 36 to 45×10^{-7}; fair glasses 46 to 55×10^{-7}, whilst those with expansion greater than 66×10^{-7} were to be regarded as inferior. These limits, it would seem, are very stringently drawn; but the proposal indicates the importance of thermal expansion in producing resistance to heat changes in the case of glass.

The co-efficient of expansion of glass is intimately connected with its composition and it has been found possible to make glasses of linear thermal expansion varying between 30 and 130×10^{-7} so that on the one hand the expansion can be made much the same as that of a number of metals, and at the other extreme, approaching that of fused quartz.

These results can be traced back to the systematic work of Schott and his co-workers at Jena. Schott himself, in 1892, collated the existing information on the thermal expansion of glasses and showed that the different constituent oxides had each a definite effect on the total expansion of the glass. A year later, in conjunction with Winkelmann, a more definite value was assigned to the individual oxides, and the calculation was made of so-called "expansion factors" which represented the contribution which each one per cent. of the particular oxide made to the total cubical expansion of the glass. In other words, the co-efficient of expansion was shown to be additive in character and capable of calculation from the formula :—

$$3\alpha = p_1a + p_2b + p_3c + \ldots\ldots\ldots\ldots\ldots$$

p_1, p_2, p_3, etc., being the respective percentages, and a, b, c being the expansion factors for the constituent oxides.

The following expansion factors were calculated by Winkelmann and Schott :—

(3) Sprechsaal, 1917, 1. 90.

B_2O_3	0.1	Li_2O	2.0
MgO	0.1	BaO	3.0
SiO_2	0.8	PbO	3.0
ZnO	1.8	CaO	5.0
P_2O_5	2.0	Al_2O_3	5.0
As_2O_5	2.0	K_2O	8.5
		Na_2O	10.0

Since the publication of Schott's work, very little additional research has been carried out on (4) the relationship between expansion and composition until the last four or five years in the author's laboratories. It has been found that some of Winkelmann and Schott's factors need revision, the effect of magnesia, for example, not being nearly as advantageous as the earlier factor would lead us to suppose, whilst the value of boric oxide we have found only to apply to glasses containing a limited percentage of that constituent. It seems difficult to believe that these factors, derived empirically, can hold good over a wide range of composition; or that an additive relationship can apply to a complex mixture of silicates, borates, etc. For ordinary commercial glasses so far made the factors do make it possible approximately to calculate the expansion.

The results of Schott's work had immediate practical application in the manufacture of heat resisting glasses. Thermometer glasses of low depression constant and fairly low expansion represented one type. The Jena chemical glassware constituted another; and, indeed, it may be stated in general that practically all the modern glasses used for chemical ware are not only resistant to corrosion, but also in varying degrees heat resisting. Silica and boric oxide, for instance, increase the resistance, particularly to water and acids, as well as diminish the co-efficient of expansion. Lamp chimneys and miners' lamp glasses at Jena were made from a glass constituted largely of silica, boric oxide, antimony oxide and sodium oxide(5).

It will be seen from the table of expansion factors that two oxides in particular, namely, silica and boric oxide, are associated with small expansion. The following analyses of six types of heat resisting glasses will illustrate the extent to which these two oxides have been used in modern times.

(4) Although mention must be made of the extension of the above table by Havas and Meyer, Sprechsaal, 1911, xliv, 188, especially to include oxides and fluorides used in enamels.

(5) E. Zschimmer, Die Glasindustrie in Jena, 1909, publ. E. Diederichs, Jena.

	Kavalier's Combustion Tubing.	Austrian "Sun Brand" Lamp Glass.	Jena Thermometer 59III	Jena "Best" Lamp Glass.	British Miner's Lamp Glass.	Pyrex Glass.
SiO_2	79.57	76.78	71.95	73.88	64.1	80.62
B_2O_3	—	—	12.00	16.48	22.0	11.90
As_2O_5	—	—	—	0.73	trace	0.66
Sb_2O_5	—	—	—	—	1.1	—
Al_2O_3	0.32	0.72	5.0	2.24	1.9	2.00
Fe_2O_3	0.04	trace	—	trace		0.14
CaO	7.80	6.52	—	„	0.5	0.22
MgO	0.11	0.24	—	„	0.1	0.29
PbO	—	—	—	—	0.6	—
Na_2O	0.66	11.14	11.0	6.67	9.7	3.83
K_2O	11.60	4.74	—	trace	—	0.61
Co-efficient of Linear Expansion A.	69.8×10^{-7}	83.0×10^{-7}	64.5×10^{-7}	46.7×10^{-7}	56.3×10^{-7}	37.2×10^{-7}
B.	—	—	$57. \times 10^{-7}$	—	—	32×10^{-7}

A. Calculated by Winkelmann and Schott's factors.
B. Experimental, 0°—100°C.

Linear thermal expansion of ordinary	soda-lime glass	about	100×10^{-7}
„ „ „ „ „	potash-lead glass	„	90×10^{-7}
„ „ „ „ „	porcelain	„	36×10^{-7}
„ „ „ „ „	cast iron	„	102×10^{-7}
„ „ „ „ „	wrought iron	„	119×10^{-7}
„ „ „ „ „	copper	„	167×10^{-7}
„ „ „ „ „	zinc	„	258×10^{-7}

In the well-known combustion tubing glass made by Messrs. Kavalier, the most important constituent is the silica which reaches the very high value of more than 79 per cent. Successful combustion tubing which has been made in this country also possesses a very high silica content. In Kavalier's combustion tubing, boric oxide is not present, and the basic oxides used as fluxes, namely, the potash and the lime, prevent the production of a low expansion glass.

The modern glasses contain, as will be seen, boric oxide in very considerable amount. Pyrex glass, the most notable of glasses in recent years, contains roughly 80 per cent. of silica and 12 per cent. of boric oxide, and there is a tendency in the manufacture, both of chemical glassware and of heat resisting ware, to make them strongly acid in character, since the acid oxides, silica and boric oxide, are far superior to the basic oxides in giving low expansion.

In practice, the use of silica and of boric oxide beyond a certain limit is attended by certain difficulties. In the case of silica the difficulty is merely that of attaining a sufficiently high temperature. Fused quartz and the semi-fused vitreosil are now well-known. They have been used for a variety of scientific apparatus and within the last few years vitreosil lamp chimneys have had a considerable demand. The very small co-efficient of expansion of fused silica (5.5×10^{-7}) makes it possible to heat articles of this material to a red heat and to plunge them into water without fracture.

For the melting and working of such glass, however, the electric furnace is needed and the mode of manufacture necessarily differs from that to which the ordinary glass manufacturer is accustomed. Naturally, also, whilst sand or powdered silica is cheap, the energy consumed in reaching the necessary temperature for fusion is expensive.

Boric oxide, on the other hand, and borates in general, fuse readily, and both borax and boric acid have been used in the glass industry for a long period as fluxes. The combination of low expansion and ready fusion is a fortunate one. There are, however, certain drawbacks to the use of boric oxide beyond a certain limit in glass. Sullivan(6) and Taylor, in giving an account of the development of Pyrex glass stated that they were forced to limit the amount of boric oxide because of the diminished durability of the glasses produced when a large amount of boric oxide was present. It has been and is still generally believed that the introduction of boric oxide into silicate glasses greatly improves the power of the glass to withstand the action of water and acids; this is not true without qualification. Some years ago in a paper from the author's department at Sheffield, it was pointed out that boric oxide beyond a certain amount was of very doubtful advantage. Recently, systematic investigations in the Department of Glass Technology, Sheffield, have shown that on the substitution of boric oxide for silica in a glass composed of silica, boric oxide and soda, the amount of the latter being kept constant, the durability rises to a maximum and then rapidly diminishes.

This fact is brought out very definitely in Fig. 1, in which the percentage of sodium

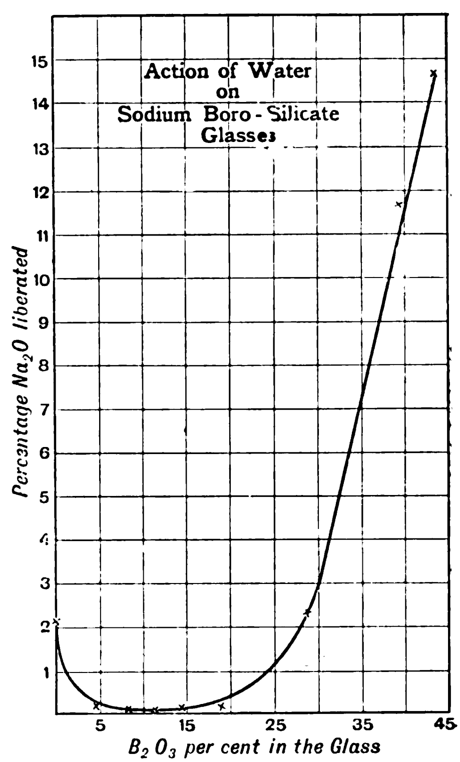

Fig. 1.

oxide extracted from the glass on boiling the latter in the state of powder of 20 to

(6) J. Soc. Chem. Ind. 1916, xxxv., 513.

30 mesh for one hour is plotted against the boric oxide content of the glass.

It will be seen that there is at first a rapid improvement in the durability, but the maximum is reached for this particular type of glass somewhere in the neighbourhood of 11 to 12 per cent. of B_2O_3. Thereafter, the durability rapidly diminishes until when 40 or more per cent. of boric oxide is present, the glass rapidly breaks up, more rapidly indeed, than does sodium silicate.

This fact alone would render glasses of high boric oxide content incapable of ordinary use; but it is not the only important fact. What is equally important from the point of view of heat resisting glasses is the fact that the reduction in the co-efficient of expansion which occurs on introducing boric oxide is also limited to a certain range, and when this range has been exceeded, the co-efficient of expansion once more increases. In other words, there is a certain minimum value of thermal expansion obtained by the use of boric oxide, and beyond that the expansion increases.

Fig. 2 represents graphically some results which have recently been obtained at Sheffield for two series of glasses, namely, one with approximately 20 per cent. Na_2O, the other with 10 per cent. Na_2O, the silica in each then gradually being replaced by boric oxide. The figure indicates that the minimum coefficient of expansion is reached in both glasses at approximately 20 per cent. of boric oxide.

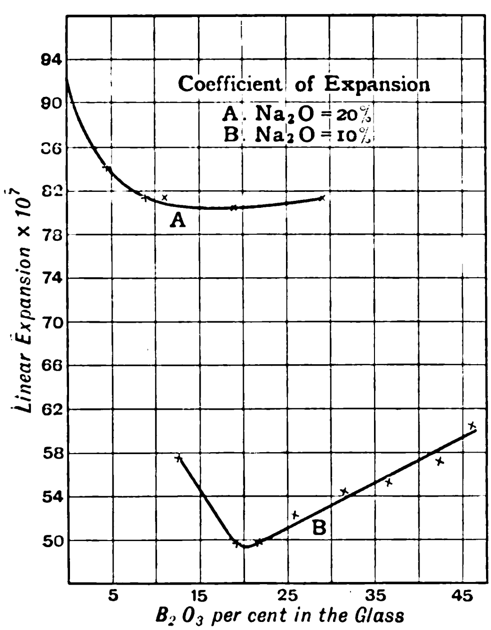

Fig. 2.

It will be understood, therefore, that whereas the only factor limiting the use of still higher proportions of silica in glass is the design of a very high temperature furnace with refractory materials better than fireclay, the boric oxide on the other hand, has its limitations because after a certain concentration has been reached: not only does the glass become unstable, but the expansion also increases.

Nevertheless, by the combination of these two oxides in boro-silicate glasses big advances in the industrial arts have been made possible. We are already well acquainted with the productions from the Jena factory. In recent years the chemical and scientific glass industry has also been built up in this country and all the chemical glassware made has been of the boro-silicate type. Miners' lamp glasses were only produced in bulk in this country after the outbreak of war, and as will be seen from the analysis of one type quoted, the glass again is composed mainly of silica and boric oxide.

In addition to miners' lamp glasses, other types of illuminating glasses, lamp chimneys, etc., are being made from glass similar in type to that used for miners' lamps. Specimens of such glasses are included in the exhibit, being shown by Messrs. Chance Bros., Glass Co., and Messrs. Ackroyd & Best.

It was the Corning Glass Co., of America, that led the way in the new development of using glass for baking and cooking dishes, and this development has already assumed big proportions. Two or three works in America, in addition to the Corning factory, make glass cooking ware under licence from the Corning Company. The H. C. Fry Company, of Rochester, U.S.A., also has produced ovenware for about four years. In this country Messrs. Ackroyd & Best are making cooking ware and the manufacture in Great Britain is likely to be extended. Messrs. Kavalier, in Czecho-Slovakia, are the latest firm to come on to the market with heat-resisting ware for domestic purposes. In addition to all kinds of dishes, they are making tea pots and coffee pots. The Corning Glass Co. is now also making tea pots of Pyrex glass and feeding bottles. Finally, the

H. C. Fry Company has recently introduced tea cups of the same glass as they employ for ovenware.

Examples of practically all these products are exhibited through the kindness of the firms mentioned.

Glasses of the boro-silicate type not only have a low thermal expansion but are also hard and of considerable mechanical strength. They are etched by hydrofluoric acid only slowly, and sand blasting or an enamel has usually to be employed for marking purposes.

The softening point of the heat resisting glasses is also high. Definite softening, as indicated by the annealing temperature, of ordinary potash-lead glass occurs at 450°-460° C.; of soda-lime glasses at 540° C. and upwards, according to the amount of lime; of miners' lamp glasses about 590° C.; of several types of boro-silicate chemical glass about 630° C. Pyrex glass has a softening temperature of about 800° C., although under pressure maintained for some time it will begin to yield at about 600°.

The mechanical strength of Pyrex glass has led the Corning Co. to commence its exploitation for other purposes than those already mentioned, and large dishes, pipes and towers for chemical plants have been made, whilst for high-tension insulators claims are made that it is superior to porcelain.*

In the earlier part of last year both the scientific and the industrial world were much exercised over the reported discovery in Czecho-Slovakia of unbreakable glass. The sensational accounts which were given of this new product recalled the glowing descriptions which were made at the time of the hardened glass of de la Bastie. According to the account of the new discovery, announced in the Times Trade Supplement of March 4th of last year, the new glass could be dropped from a height of 12 feet, or could be made very hot and plunged into water, without fracture, whilst hammers made from it could be used to drive hard nails into wood.

It was my privilege during last summer to visit the factory at which this so-called unbreakable glass was being developed, and the proprietors, namely, Messrs. Kavalier, gave me clearly to understand that the sensational statements made in regard to the glass did not have their approval. They showed me, indeed, that the glass was not unbreakable, but it was exceptionally tough and highly resistant. Because of the sensational statements which had been made in regard to the glass they were withholding it from the market until its properties could be tested scientifically and an authoritative report obtained on it. Samples, I understand, will soon be commercially obtainable.

In an endeavour to peep into the future and forecast possible developments, one realises that there is at least one avenue down which investigators may press with assurance and others which are tempting.

In the first place, we already are familiar with the valuable properties of fused silica, and the problem, already indicated, is to discover refractory materials which will withstand the action of fused silica, with or without small additions of other oxides, at temperatures of 1,550° to 1,750°. Pyrex glass is melted in tank furnaces operating at a temperature not less than 1,500°, so that notable advance has been made in regard to high temperatures in the glass industry. Open hearth steel furnaces are operated at temperatures somewhat higher still, so that no great difficulty is likely to be experienced in proceeding to a further stage when once the suitable furnace material is forthcoming. Active search is being made for it now.

So far as the use of other oxides is concerned, the field is not exhausted. Thus, zirconia(7) has a linear expansion coefficient of 8.4×10^{-7}, only little inferior to fused silica, but with a melting point of about 2,600° C. Clearly this oxide is first likely to find use, not in the pure, fused state, but as an addition to silica(8), and the same is true of other refractory oxides, such as titania and thoria. Havas and Meyer, in their work on the expansion of enamels, calculated the expansion factors of zirconia and titania as 4.1 and 2.1 respectively. Such comparatively high values would give no encouragement to the hope of using these oxides in low expansion glasses, but the high value for zirconia is not in keeping with its low co-efficient of expansion.

Already some preliminary attempts have been made to produce glasses by adding

* A. E. Marshall J. Ind. Eng. Chem. 1923, xv., 141.

(7) H. Arnold, Chem. Zeitung, 1918, xlii, 413, 426 and 439.

(8) The addition of silica to zirconia does not, it may be remarked, result in any very great reduction in the melting point of the latter. See E. W. Washburn and E. E. Libman, J. Amer. Cer. Soc. 1920, III., 634.

small amounts of titania and zirconia to silica, the objects being to increase the resistance of the fused silica to devitrification and to attack by basic materials. The general results stated to be achieved are the production of a glass(9) having superior mechanical properties and thermal properties to vitreosil, although actual numerical data have not been quoted.

Other experiments have undoubtedly been made in factories with glasses containing a series of oxides, including titania, to test specific points, but information has not been forthcoming, and perhaps not obtained, of the effect on thermal expansion. At Sheffield we have found it possible to add both zirconia and titania to ordinary glasses. In regard to titania present in glasses containing silica, soda and titania, the last-named oxide does bring about a big reduction in the co-efficient of expansion when it substitutes soda. It is, however, per cent. for per cent. by weight, not so effective as magnesia, although it appears to be better than most basic oxides. There is, however, a very considerable increase in the toughness of the glass as titania is added, and it may be noted that when several per cent. of titania are present, small crucibles of glass can be cooled down without special precautions to yield unbroken lumps. Given the requisite optical properties, it is conceivable that the addition of either zirconia or titania to optical glass might make it possible to obtain a bigger yield of glass from an optical glass melting by reducing the amount of splintering. In the presence of reducing gases, unfortunately, titania glass tends to be dark brown in colour, although it is possible to retard such colour development.

Progress in the endeavour to increase the mechanical strength of glass might first profitably be made in a systematc determination or redetermination of the relationship between the tensile, compression and other mechanical properties and the chemical composition. The Jena workers have already drawn certain conclusions as to the effect of different constituent oxides and additive relationships established, but in the author's view, their results need revision.

As to the possibility of heat treatment, we have to remember that until devitrification sets in, glass contains no crystalline structure, the units of which could have their boundaries modified, as is possible in metals, by cold working or by heat treatment. Owing to its brittleness, glass hardened by quenching possesses an element of risk, since when the outer layers are broken through, the mass is at once reduced to powder.

(9) F. Thomas, Chem. Zeitung, 1912, xxxvi., 25. F. Wolf-Burckhardt and W. Borchers, French Pat. 432, 786.

DISCUSSION.

The Chairman (The Hon. Sir Charles Parsons) in opening the discussion, said he should like to make one or two remarks with reference to the physical state of glass. In the gauge tube made by the Schott method in two layers, the inside layer having a less co-efficient of expansion and contraction than the outside layer, it followed that when the glass cooled, the inside layer was in compression. It was both in compression in a longitudinal direction and also in a circular direction. Neglecting the longitudinal compression, the inside layer was exactly like the barrel of a large gun, where designedly the coils were either shrunk on or it was wound externally with steel wire, the object being to put the inside in a state of compression within the elastic limit. The result was that when the gun was fired the tensile stresses became equally disturbed and each concentric tube of the gun bore its share in the stress. He believed this to be the main advantage of the Schott tube, and that it would stand a higher steam pressure than a plain tube. If a plain tube was subjected to heavy internal pressure, the inside layers would be stressed more than the outer, and the stress would be inversely proportional to the radius of the layer under consideration.

He would like to allude to some instances of fractures of glass by heat which had come under his personal observation and received careful investigation. Apart from questions of want of homogeneity in glass caused by its treatment during founding or owing to the presence of stones or other foreign matter, fracture of glass took place when the tension at any point somewhat exceeded the elastic limit of the glass.

The tension was primarily proportional to the temperature gradient in the glass, and proportional to its co-efficient of expansion; it was also influenced, to some extent, by the form of the piece of glass under consideration, and the smoothness of its surface.

In the case of large parabolic mirrors for searchlight projections, the glass being about ⅝ inch thickness and silvered on the back, frequent fractures took place when attempts were made to increase the power of the arcs—investigation by thermo couples inserted in holes drilled in the glass to different depths

showed that fracture was caused by excessive temperature gradient in the direction normal to the surface. The difficulty was eventually overcome by using a boro-silicate glass according to Sir Herbert Jackson's formula with about one half the co-efficient of expansion of ordinary plate glass and alternatively by reducing the thickness of the glass to one half.

Fracture of the condensers used in cinema projection lanterns had also been a source of considerable trouble, and had, to a large extent, been overcome by the use of a glass with small co-efficient of expansion.

There was another rather illuminating fact. One of the tests of some descriptions of glass bottles was that they should stand being filled with boiling water. If perfectly annealed the glass would not stand the test; it fractured; but, if, after it was blown in the mould, it was taken into the layer and cooled rather rapidly, it stood the hot water test. Why was that? When the glass set, that was the time when all the stresses were fixed. If, at the time of settling, there was a difference in temperature, and the outer layer was colder than the inner layer, then, when the bottle was quite cold, the outside would be in compression, and the inside in tension. When hot water was poured into it, the heat gradient was in the same direction, viz., the inside was hotter than the outside, and it was the same heat gradient as was imposed on the glass when the glass was setting by being cooled rapidly in a layer: it then stood perfectly. Taking an ordinary glass, any of the heat treatments of quenching in oil, and so on, simply induced certain stresses which enabled the material under certain other treatment to stand, because that treatment relieved the stresses instead of increasing them, and the initial stresses made it stand those induced stresses better.

Everyone was familar with the work that had been done by Sir Herbert Jackson and Dr. Esslemont during the war on glasses of all descriptions. While before the war little was known in this country about many of the glasses which the Germans made, we now had at our disposal quite as good, if not better, glasses than the Germans.

Sir Herbert Jackson, K.B.E., F.R.S., said he supposed the day of toughening glass was gone. Certainly those who, in the early days, had been asked to try toughened glass for chemical work used to have the interesting experience of watching the flask, after it had been scratched on the sand bath, slowly sink into a heap of powder or rapidly explode about the room. But there was one application of the old toughening which might not be known to everybody present and which was sometimes quite useful. It was well-known to those who worked in ordinary soda lime silicate glasses that those glasses did not hold platinum wires unless those wires were very thin; the glass inevitably cracked. If one had not the proper enamel for sealing in, one might be unable to carry out an experiment, but by taking advantage of the toughening of the glass one could always get over the experiment (if a permanent piece of apparatus was not required) by putting wire in, fusing the glass well round it, and then plunging the whole thing into a piece of solid paraffin. It would not crack, but it was not a thing that one would leave as a safe joint to keep and trust to when one desired to go on. It might last weeks or months but it was not in a stable state.

He had been very much interested in the author's remarks in connexion with the boro-silicate glasses and the experience in the early part of the war—in December of 1914 or the early part of 1915—when those matters were first investigated in connection with the Glass Research Committee of the Institute of Chemistry. It had been possible, by using extremely finely divided silica, and boro-anhydride, and by long heating in platinum crucibles, to make a very nice looking glass with very considerable thermal endurance. He himself had started in that direction in order to study the stability of the glass in the way the author had described. It was interesting to recall that when such a glass was placed in a little water in a beaker on the night on which the experiment was finished, the next morning there was nothing but a jelly of hydrated silica and a lot of crystals of boracic acid; the glass had gone entirely. What was then done was progressively to add 1, 2, 3, 4 to 20 per cent. of soda, passing on the way glass of the Pyrex type. The reason why this harder glass was not adopted was because war conditions had had to be thought of at that time, and he found that so high a temperature was required for making it that it was hardly possible to recommend it then to manufacturers. But there was no question whatever that the higher temperature glass was very convenient in some respects, and it was a most interesting glass.

With regard to titania glass, he had not been struck at all with the alteration in the thermal properties of titania glasses, but there was one property of titania in glass which he thought was worth following up. Taking an ordinary sodium calcium silicate, like a common window glass, it was almost impossible to blow a bulb out of that in the blow pipe on account of the rapidity with which it devitrified. One per cent. of titania would enable one to blow quite a good bulb; 2 per cent. would enable one to blow that bulb in and out five times; and with 5 per cent. he had reached 80 times blowing a bulb in and out without any devitrification at all. Therefore, he thought titania had a definite future in that respect if it could be obtained cheap enough. One point with regard to it which might be worth mentioning was that if the glass was hard enough there need be no fear of reduction of titanium in the ordinary blow pipe flame.

Thoria was not yet a cheap material. The most striking property he knew of—apart from optical qualities—was that a very high temperature was required to make the glass, but it had a singular plasticity afterwards—what he would call a long range of plasticity. He was inclined to think that the plasticity of a glass was not sufficiently recognised in dealing with resistance to fracture. He would like to remind the audience of a remark which he had previously made in that room, namely, that a glass that would equally take copper and platinum wires could be made which would not take iron wires sealed into it without cracking. It was difficult to believe that coefficient of expansion was the only factor there, because the coefficient of expansion of copper was double that of platinum, and iron was practically just the mean between the two. For hard metals like iron, nickel and tungsten, a glass which might be described as having some plasticity over a good range of temperature, was aimed at, and such a glass had been obtained into which moderately stout wires of hard metals could be safely sealed.

Sir Richard A. S. Paget, Bt. (Chairman of the Thermal Syndicate, Ltd.), said the author raised the question as to the scale on which silica could be fused. As a matter of fact, that scale was now pretty considerable. It was possible to make pipes, for example, two feet in diameter which were quite suitable for various chemical purposes, and he saw no reason why it should not be possible to make very much larger articles if there were a demand for them in the big chemical industries. There was one thing he would like to mention in connection with the effects of adding zirconia in particular. As the author had stated, attempts had been made in Germany before the war to add zirconia and also similar oxides to silica, and it had been claimed that those additions made an entirely different material. The author suggested that that was done in the hope of getting various physical results. His own impression was that the hope was mainly a commercial one; it was hoped that by adding those materials to silica a substance would be obtained which would be outside the patents of the Thermal Syndicate! It had had to be bolstered up, however, with some physical claims as well, and it had been really on that side that the thing had failed. His Company had made some systematic experiments. They had been actually conducted by Dr. Mickie, acting under the late Dr. Bottomley. Dr. Mickie had found that so far as devitrification was concerned, the more zirconia was added the quicker the silica devitrified, so that in that respect, the claims were not apparently well founded. He did not know—and he would be much interested if the author could give any information—of any mechanical increase in strength or of any lowering of the melting point. As far as his own knowledge went, he did not find any advantage in mechanical strength, and he did not think there was any material difference in the melting point by adding relatively small quantities, as the Germans did, of zirconia or titania.

There was one other point which it might be interesting to mention. He did not think the author actually had compared the co-efficient of expansion of pure silica with that of the various glasses mentioned, but it would appear that the co-efficient of expansion of Pyrex—the lowest which the author had given—was still seven times that of fused silica. So that it would be seen there was a very wide range of difference between the material which started from pure silica and that which started from glass and tried to obtain a lower coefficient of expansion in a material which could be worked in the ordinary glass making furnace.

Mr C. C. Paterson (Research Laboratories of the General Electric Company) said he had listened with very great interest to the lecture. The industrial development of refractory glass was a matter of the greatest importance, because it was becoming an essential of many branches of industry. A glass was required which would melt, and be worked reasonably easily and yet would be able to stand up to severe thermal treatment. The question of sealing metals into such glasses was one of importance, and he had been interested to hear what a previous speaker had said regarding the difference between copper and iron.

It had to be remembered that the pliability of the metal sealing wire itself probably entered into the question, because if the sealing wire gave a little when the stress came on, it might still hold up a seal and prevent its cracking, although its co-efficient of expansion was not correct.

Mr. Noel Heaton said that Professor Turner had dealt with his subject so clearly and comprehensively that it left little room for discussion. Before the meeting he had had a very hazy idea as to the lines of recent research on the question of thermal endurance. The author had made that point perfectly clear. It seemed that practically the only solution of the problem was to work on the chemical side, and to abandon the attempts at mechanical treatment of the glass to obtain thermal endurance. As those familiar with toughened glasses knew, those glasses were as unreliable as they could be; whereas by attacking the matter on the chemical side, one seemed to be able to get glasses which tended to approximate to the properties of pure silica. One thing about which he was disappointed was that the author had not found titania of much help, because that was a matter in which he had been particularly interested for some time.

Mr. Walter Hancock said one minor point which had interested him was whether the author could give some idea of the temperatures necessary for working, say, the Pyrex glasses in the furnace, and whether they had or had not a long range of viscosity. With regard to the introduction of titania and zirconia into glasses, he remembered that some years ago, when the original patent (which to the best of his knowledge was in French) had been brought out, it looked as though one was really coming up against some new and far-reaching discovery. Speaking from the point of view of the effect of titania as it was met with in refractory materials, one would have expected that the reduction in the melting point would have been considerable. He would also like to ask the author if he could give any idea as to the effect of those glasses containing proportions of titania, more particularly upon the refractory materials with which the melt was bought in contact—whether it had any great penetrating effect, for example, upon fire-clay materials.

Mr. E. A. Coad Pryor said there was perhaps one point which the author had not emphasised as much as he might have done, and that was the question of elasticity. The more one worked on glass the more one was appalled by its peculiar elastic properties, and the more one was inclined to think that the condition of the glass—perhaps the structure—played a very important part in the thermal endurance. One had only to consider the test made on a number of articles of uniform thickness and of the same composition manufactured at the same time by a machine; if there were a hundred articles, and heat was suddenly applied, perhaps ten per cent. would go at 60°; another 5 per cent. at 70°; another 20 per cent. at 100°; another 20 per cent. at 110°, and so on, showing that there was a very remarkable variation in the thermal endurance with some rather ephemeral property which had not been quite elucidated. Certain experiments made one rather believe that methods might be discovered of making glass with a comparatively high co-efficient of expansion which might be very resistant to changes of temperature without the usual methods of hardening. The effect of cold work on glass was very remarkable, and the effect of that cold work was the more remarkable when the glass was annealed thoroughly after the cold work had been applied. That might possibly have some analogy in the effect of the annealing of strained metallic specimens. He thought there were lines of development, quite apart from the easily measurable physical constants, which might lead to the hope that, with the increasing knowledge of the constitution of glass, material with a higher thermal endurance might be produced.

Dr Reginald S. Clay said he would like to ask a question with regard to the internal cooling to which the Chairman had referred, which was used in making soda water bottles. The Chairman had explained very clearly that that treatment enabled the bottle to withstand a sudden change of temperature produced by pouring hot water into it, because the heat would relieve the strains, but if soda water bottles so treated were dipped into hot water the reverse would occur: it would increase the strains. Could the author state whether, in that case, the soda water bottle would break more easily than it would have done if it had been properly annealed? Also, did the composite tubes to which the author had referred in which, in some cases, a glass of higher co-efficient of expansion was on the outside, and in other cases, on the inside, break equally easily if the heat was applied to the outside? Or would one tube stand up against hot water poured on the outside, while the other one would stand up against a similar treatment on the inside? With regard to the sealing in of electric leads to which Sir Herbert Jackson had referred, was the reason why platinum and copper were successful and not iron, due to the wetting of the glass by those metals? If iron did not wet the glass, one could understand that the glass might break down under stress in very much the same way as glass that was strained broke down when it was scratched or the surface was otherwise disturbed. There would be a place of weakness where the iron went through, which would spread, whereas if the glass was really wetted by the metal, as he believed it was with platinum (he did not know whether it was with copper) that would help to keep the whole in a state of equilibrium. He could hardly imagine it was due to the plasticity of the copper, as it would shrink away from the glass as it cooled. It might give here and there if the strains were unequal, but that would not be enough, he thought, to account for the fact that copper, with its high co-efficient of expansion, can furnish a sound seal.

The Author, in reply, said the audience had been very fortunate that evening in having present Sir Charles Parsons, Sir Herbert Jackson and Sir Richard Paget, who had all added very valuable information to the subject from different aspects. A good deal had yet to be learned about the power of uniting metals to glasses, and also different kinds of glasses to one another. In coming into contact with actual manufacturers' problems, he had frequently found that with two glasses which were supposed to be capable of uniting—*e.g.*, where it was desired to flash a coloured glass on to a colourless glass—similarity of co-efficient of expansion was not the only secret of success. One very observant manufacturer had definitely stated to him that more often

than not he had found that if he took his basic glass—the colourless glass—and added to it some colouring oxide, the amount of which was usually very small, the coloured glass did not unite well with the colourless and had to be softened by a distinct change of composition before union could be made successfully, and the article be able to withstand cutting. He (the author) made this statement with due reserve, and with the remark that the problem deserved investigation. The plasticity of glass from the point of view which Mr. Coad-Pryor had emphasised, did present some striking features. A few months ago in America, one worker had directed attention to the strain which was induced in glass by high pressure, and he had declared that, notwithstanding the glass was maintained at a temperature above the annealing temperature, the action of the pressure—especially when pressures of about 5,000 lbs. to the square inch had been used—did bring about a considerable degree of strain and the glass could not be readily annealed. Mr. Coad-Pryor had referred to the effect of cold working. They at Sheffield had had the extraordinary experience of a glass, whose annealing temperature they knew, which could not be annealed at that temperature nor yet at 20°, or even 150° above that supposed annealing temperature. The glass required absolutely thorough softening, accompanied by deformation to restore it to its normal condition. A question had been asked, which he thought had been really directed to the Chairman, about the cracking of soda water bottles. The Chairman had referred to the fact that such bottles, when the exterior was under compression due to chilling and imperfect annealing, could be plunged into hot water without being cracked. The enquirer had asked whether, if the water were poured inside, the bottle would crack. He would just remark in reply, that one or two firms of glass manufacturers had tried a process in making jam jars, of chilling the interior. That process they found made it possible for the glass to withstand the shock of heat applied internally when jam was poured into them. So one had the reverse of the cause which the Chairman had mentioned, and which might be an answer to the question.

With regard to the working of the boro-silicate glasses with a very high silica content, it was generally known that boro-silicate glasses—the chemical glasses and so on—must be melted at a high temperature, and in regard to the Pyrex glass, the temperature of the melting end of the furnace would not fall below about 1500° Centigrade. Another feature of those glasses was that the viscosity range was very small. The glass soon became very stiff and difficult to work. Pyrex glass was melted in a tank furnace, and he believed that the drop between the melting end and the working end of the furnace only amounted to something like 50°C; that was to say, a drop from about 1500° to 1450°. Auxiliary oil burners had from time to time to be used and applied in order to maintain the glass in a working condition. With regard to the effect of the boro-silicate glasses on refractory materials, the makers of Pyrex glass knew how marked could be the attack. The attack, however, came mainly from the boric oxide and not from the silica. If the proportion of boric oxide was increased, then the attack became all the greater; but, on the other hand, in making glasses of that kind, the greater the proportion of boric oxide, the quicker the melting took place, whereas glasses which had high silica and moderately low boric oxide content, were slow in melting and by long continual action on the refractory material produced brown colourations in various shades. With 40 or 50 per cent. boric oxide, an absolutely colourless glass could be obtained merely because the melting period was cut down so very greatly. It might be cut down to a third or a quarter or a fifth of the time needed with higher silica and lower boric oxide.

On the motion of the Chairman, a hearty vote of thanks was accorded to the author for his valuable paper, and the meeting terminated.

NOTES ON BOOKS.

Synthetic Colouring Matters. Vat Colours. By Jocelyn Field Thorpe and Christopher Kelk Ingold. London: Longmans Green & Co. 1923. 16s. net.

The present volume, comprising xvi and 492 pages, is next in sequence with Hewitt's "Synthetic Colouring Matters: Dyestuffs derived from Pyridine, Quinoline, Acridine and Xanthine," which was reviewed on pp. 236-237 of the *Journal* dated February 15th, 1923, and the volumes promised by Messrs. Longmans & Co., as in preparation, comprise one on Sulphur Dyes, by G. T. Morgan and A. E. Goddard; Azo-Dyes, by F. W. Kay; Triphenylmethane Dyes, by R. Robinson; Anthracene and Allied Dye-stuffs, by F. W. Atack, and Azine and Oxazine Dye Stuffs, by J. T. Hewitt.

The promise of the two volumes already in our hands is such as gives hope that the series, as a whole, will, when completed, form a conspectus of the synthetic colour industry such as has never before been projected in Great Britain, and comparable in completeness with the works of Friedländer.

Drs. Thorpe and Ingold devote nearly twenty pages to the early history of dyes and dyeing, and having mentioned Cæsar's reference to the use of woad in Britain, they touch on dyeing generally in the old world, as referred to by

Pliny, Herodotus, Lucretius, Virgil and very frequently in the Scriptures. As regards the Tyrian purple, they trace the legendary and known history from the Nymph Tyro or Tyros, to the discovery in 1685 that light brings about or promotes the change from white to purple. Friedländer's separation, purification, and analysis of the purple obtained from 12,000 speciments of *murex brandaris* comes as a present day climax, and on p. 19 we see displayed the constitutional formula of 6: 6′—Di-bromo-indigo, or Tyrian purple.

About one third of the book is devoted to natural indigo, artificial indigo and indigo analogues; and somewhat over another third to anthroquinone and its derivatives; the remainder being given to miscellaneous matters, but attention may be called to Dr. Levinstein's tabulation of British vat dyes on p. 459.

Authors and publishers are to be heartily congratulated on this thorough and well-wrought volume, and those who possess it will wish to have the forthcoming volumes of the series.

NICKEL. THE MINING, REFINING AND APPLICATION OF NICKEL. By F. B. Howard White. London: Sir Isaac Pitman and Sons, Ltd. 1923. 3s. net.

A general reader who requires a vividly written and illustrated account of the many recent uses of nickel should be charmed with Mr. White's well-indexed booklet of x. and 118 pages. The ordinary formal particulars as to nickel and its compounds as usually found in our text books of chemistry are happily ignored by the author, but he rather enlarges on copper whitened by one-fifth, more or less, of nickel; an alloy which appears to have been used long ago for making coins and small articles. One specific mention of the old time use of such an alloy for coinage is its issue about 2158 years ago, in Bactria or Bactriana (now Bokara); then one of the short-lived Asiatic *quasi*-Grecian States which arose after the Macedonian conquests in Persia.

Mr. White refers to the Bactrian coins as showing on analysis about one-fifth of nickel and suggestive of four-fifths of rather impure copper: thus showing a similarity with our various modern whitened-copper alloys, known as German silver, Albata, Neusilber, Nickel silver and Paktong; alloys unsatisfactory as coinage, and sometimes dangerous for culinary use by reason of the ease with which acid comestibles dissolve out copper, and also zinc if present.

The book is, in effect, a summary of the modern methods of producing almost chemically pure nickel, and the industrial applications of pure nickel, which, by-the-by, can be instantly distinguished from the above mentioned alloys by the fact that the pure nickel is readily attracted by a magnet, whereas the presence of one-twentieth of a non-magnetic metal will subvert this property.

For this reason, and because pure nickel requires expensive plant and machinery for preparation, rolling and coining, there is but little fear of spurious coins coming into circulation, even when the pure nickel is used to replace silver coins. The chapter on nickel coinage gives much detailed material, tabular and otherwise.

The Mond process, described in Chapter IV., may yield nickel so nearly pure as to contain 99.9 per cent. of the metal: the final stage in this process (p. 23) is a kind of distillation in an atmosphere of carbon monoxide, it being a remarkable fact that several of the highly refractory metals form readily volatile compounds; chromium and osmium for example. Although other methods of refining are now practised, it is the Mond process which has made nickel an industrial product of primary importance.

Among the many applications of pure nickel which are illustrated and treated of, are its uses for cooking vessels, military food containers and ionic valves.

Somewhat full details are given of the various nickel-steel alloys, modern practice in nickel plating, electric heating devices with nickel-chromium wires, and of the uses of nickel as a calalyst in hardening fatty materials by hydrogenation.

MEETINGS OF THE SOCIETY.

ORDINARY MEETINGS.

Wednesdays at 8 p.m., except where otherwise stated:—

MAY 9.—WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Surface Combustion, with special reference to recent Developments in Radiophragm Heating." D. MILNE WATSON, M.A., LL.B., Governor of the Gas Light and Coal Company, will preside.

MAY 16.—L. GASTER, "Industrial Lighting and the Prevention of Accidents." SIR MALCOLM DELEVINGNE, K.C.B., Assistant Under-Secretary of State, Home Office, will preside.

MAY 30 (at 4.30 p.m.).—A. J. SEWELL, "The History and Development of the Perambulator and Invalid Carriage."

INDIAN SECTION.

Friday afternoons.

JUNE 1, at 4.30 p.m.—AUSTIN KENDALL, I.C.S., rtd., "The Indian Section of the British Empire Exhibition, 1924."

JUNE 15, at 4,30 p.m.—SIR JOHN H. MARSHALL, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian

Art." (Sir George Birdwood Memorial Lecture.)

HOWARD LECTURES.

Monday evenings at 8 o'clock.

STANLEY S. COOK, B.A., M.I.N.A., M.I.M. (Parsons Marine Steam Turbine Co.), "The Development of the Steam Turbine." Three Lectures. April 30, May 7, 14.

Syllabus.

LECTURE I.—Introduction. The principles of compounding. Early indications of progress. Marine development with direct coupled turbines. Reaction and impulse blading. The problem of the propeller. Combination of turbine and reciprocating engine. The passing of the direct coupled marine turbine.

LECTURE II.—The introduction of mechanical gearing. Other types of gearing. Application of mechanical gearing to large powers in Naval Vessels. Development of the mercantile marine turbine. Comparison of modern and early efficiencies. Whirling of rotors. Lubrication and pivotted thrust blocks. Methods of attaching blades. End tightened reaction blading. LAND TURBINES: various types. Progress in economy and output. The problem of the exhaust area.

LECTURE III.—Application of mechanical gearing to land turbines. Geared turbines for mill driving. "Pass out" turbines. Geared turbo generators. Direct coupled turbo alternators. Non-salient pole rotors. Ventilation of stators. Latest improvements in economy of turbines by re-heating and cascade feed-heating.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, APRIL 30.. University of London, King's College, Strand, W.C., 5.30 p.m. Prof. R. Dyboski, "Outlines of Polish History." (Lecture I.)

King's College for Women, 61, Campden Hill Road, W., 4.30 p.m. Prof. V. H. Mottram, "Nutrition." (Lecture I.)

Farmers' Club, at the Surveyor's Institution, 12, Great George Street, S.W., 4 p.m. Col. the Hon. F. V. Willey, "Commercial Outlets for British Wool."

TUESDAY, MAY 1.. Royal Institution, Albemarle Street, W., 3 p.m. Sir Arthur Keith, "Machinery of Human Evolution." (Lecture IV.)

Anthropological Society, 50, Great Russell Street, W.C., 8.15 p.m. Mr. V. G. Childe, "The Neolithic Painted Pottery of South-Eastern Europe.".

University of London, King's College, Strand, W.C., 5.30 p.m. Rev. Percy Dearmer, "Sixteenth Century Art" (Second Part). (Lecture I.)

African Society, King's College, Strand, W.C., 5.30 p.m. Dr. A. P. Newton, "Africa and Historical Research."

Alpine Club, 23, Savile Row, W., 8.30 p.m. Mr. A. P. Harper, "The Southern Alps of New Zealand."

WEDNESDAY, MAY 2.. University of London, King's College for Women, 61, Campden Hill Road, W., 4.30 p.m. Prof. V. H. Mottram, "Nutrition." (Lecture II.)

King's College, Strand, W.C., 5.30 p.m. Dr. E. Barber, "Ethics and the Philosophy of History," prepared by the late Prof. Dr. E. Troetsch. (Lecture I.)

At the Old Hall, Lincoln's Inn, W.C., 5.30 p.m. Mr. P. B. Lambert, "Legal Phraseology."

At the University, South Kensington, S.W., 5 p.m. Sir Frederick Bridge, "Some Operatic Studies." (Lecture V.)

At University College, Gower Street, W.C., 3 p.m. Prof. E. G. Gardner, "Dante—the Composition of the Divina Commedia." (Lecture I.)

Geological Society, Burlington House, Piccadilly, W., 5.30 p.m.

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C. (Wireless Section), 6 p.m. Prof. C. L. Fortescue, "The Design of Inductances for High-frequency Circuits."

Metals, Institute of, at the Institution of Mechanical Engineers, Storey's Gate, S.W., 8 p.m. Dr. W. Rosenhain, "The Inner Structure of Alloys."

Public Analysts, Society of, at the Chemical Society's Rooms, Burlington House, Piccadilly, W., 8 p.m. (1) Mr. W. Dickson, "The Quantitative Determination of Hemp and Wood in Papers containing these two Fibres." (2) Mr. H. Jephcott, "The Estimation of Fat, Lactose and Moistures in Dried Milks." (3) Mr. A. L. Bacharach, "The Estimation of Lactose by the Polarimetric and Gravimetric Methods." (4) Mr. M. S. Salamon, "The Melting Point and Iodine Value of Refined Natural D. Camphor." (5) Mr. A. G. Francis, "The Presence of Barium and Strontium in Natural Brines."

Archæological Institute, at the Society of Antiquaries, Burlington House, Piccadilly, W., 5 p.m. Mr. P. Nelson, "Additional Examples of English Mediæval Alabaster Carvings."

THURSDAY, MAY 3.. Royal Society, Burlington House, Piccadilly, W., 4.30 p.m.

Linnean Society, Burlington House, Piccadilly, W., 5 p.m.

Chemical Society, Burlington House, Piccadilly, W., 8 p.m. (1) Mr. H. B. Baker, "Change of Properties of Substances on Drying." Part II. (2) Messrs. H. Bassett and P. Halton, "The Sodium Salts of Phenolphthalein." (3) Messrs. H. Bassett and R. G. Durrant, "The Action of Thiosulphates on Cupric Salts." (4) Messrs. R. G. W. Norrish and E. K. Rideal, "The Conditions of Reaction of Hydrogen with Sulphur" (Part II.). "The Catalytic effect of Oxygen" (Part III.). "On the Mechanism of the Reaction of Hydrogen with Sulphur and its Catalysis by Oxygen." (5) Mr. T. M. Lowry, "Studies of Electrovalency" (Part II.). "Co-ordinated Hydrogen." (6) Mr. H. Hunter, "Investigations of the Dependence of Rotatory Power in Chemical Constitution" (Part XX.). "The Rational Study of Optical Properties: Refraction a Constitutive Property."

Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.

Royal Institution, Albemarle Street, W., 3 p.m. Prof. J. T. MacGregor Morris, "Modern Electric Lamps." (Lecture II.)

Sanitary Engineers, Institution of, Caxton Hall, Westminster, S.W., 6.30 p.m. Mr. W. R. Hadwen, "The Relationship between Insanitation and Disease."

FRIDAY, MAY 4.. University of London, King's College, Strand, W.C., 5.30 p.m. (Shakespeare Association). Mr. M. H. Spiemann, "Shakespeare Portraiture—the Frontispiece."

Royal Institution, Albemarle Street W., 9 p.m. Prof. F. Soddy, "The Origins of the Conception of Isotropes."

Mechanical Engineers, Institution of (Yorkshire Section), Philosophical Hall, Park Row, Leeds, 7.30 p.m.

Engineers, Junior Institution of, 39, Victoria Street, S.W., 7.30 p.m. Mr. S. A. Stegant, "A.C. Neutral Point Earthing."

Civil Engineers, Institution of, Great George Street, S.W., 6 p.m. Sir Richard Glazebrook, "The Interdependence of Abstract Science and Engineering." (James Forrest Lecture.)

SATURDAY, MAY 5. Royal Institution, Albemarle Street, W., 3 p.m. Dr. L. L. B. Williams, "The Physical and Physiological Foundations of Character." (Lecture II.)

Philological Society, University College, Gower Street, W.C., 8 p.m. (Anniversary Meeting.) Presidential Address.

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FRIDAY, MAY 4, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICES.

NEXT WEEK.

MONDAY, MAY 7th, at 8 p.m. (Howard Lecture). STANLEY S. COOK, B.A., M.I.N.A., M.I.M. (Parsons Marine Turbine Co.), "The Development of the Steam Turbine." (Lecture II.)

WEDNESDAY, MAY 9th, at 8 p.m. (Ordinary Meeting.) WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Surface Combustion, with special reference to recent Developments in Radiophragm Heating." D. MILNE WATSON, M.A., LL.B., Governor of the Gas Light and Coal Company, will preside.

NINETEENTH ORDINARY MEETING.

WEDNESDAY, APRIL 25th, 1923, THE RIGHT HON. F. D. ACLAND, M.P., in the Chair.

The following candidates were proposed for election as Fellows of the Society :—

Anthony, Harvey Mitchell, Indiana, U.S.A.
Finch, Rev. Frederick Stephen, Bunbury, West Australia.
Girand, James B., Mem.Am.Soc.C.E., Arizona, U.S.A.
Khairpur, His Highness Mir Ali Nawaz Khan of, Sind, India.
Notvest, G. Robert, Assoc.Mem.Am.I.E.E., Cleveland, Ohio, U.S.A.

The following candidates were duly elected Fellows of the Society :—

Anjaria, Hiralal Ganeshji, B.A., Godhra, India.
Aspar, P. E., A.M.I.N.A., A.M.I.Mech.E., Bombay, India.
Barooah, Gozendro Nath, Assam, India.
Bennet, Emile J., Torquay.
Carter, William Leslie, F.C.S., Birmingham.
Case, Theodore Willard, B.A., Sc.M., New York, U.S.A.
Duncan, Prof. David Shaw, A.M., B.D., Ph.D., Colorado, U.S.A.
Gilmer, Weir Burton, Tatapuram, India.
Kalyanray, Jhaverilal, M.I.M.E., Bengal, India.
Mackenzie, Captain Ian Alistair, M.A., LL.B., M.P.P., Vancouver, B.C., Canada.
Manuja, Jaswant Roy, Lahore, India.
Nagle, James C., M.A., B.Sc., Texas, U.S.A.
Pendleton, Robert Larimore, B.S., Ph.D., Gwalior, India.
Saunders, Miss Marshall, Toronto, Canada.
Vallis, Joseph Samuel, Bermuda, B.W. Indies.

A conference on "The Milk Question" was held, at which the following papers were read :—(1) PROFESSOR R. STENHOUSE WILLIAMS, M.B., B.Sc., L.R.C.P., and S.E., D.P.H., "The Arguments for Maintaining an Open Market for Fresh Milk;" (2) PROFESSOR J. CECIL DRUMMOND, D.Sc., F.I.C., "Changes in the Digestibility and Nutritive Value of Milk induced by Heating"; (3) S. S. ZILVA, Ph.D., D.Sc., F.I.C., "The Effect of Heat on some Physiological Principles in Milk." A Demonstration of some of the Chemical Changes in Milk on Heating to various Temperatures was given by CAPTAIN JOHN GOLDING, D.S.O., F.I.C.

The papers and discussion will be published in a subsequent number of the *Journal*.

HOWARD LECTURE.

MONDAY EVENING, APRIL 30th, MR. ALAN A. CAMPBELL SWINTON, F.R.S., in the Chair. MR. STANLEY S. COOK, B.A., M.I.N.A., M.I.M. (Parsons Marine Turbine Co.), delivered the first lecture of his course on "The Development of the Steam Turbine."

The lectures will be published in the *Journal* during the summer recess.

EXAMINATIONS.

The number of entries received for the Society's Examinations this year is 68,251. This constitutes a record, and is an increase of 7,920 over the total for 1922, when the number was 60,331. For the first examination, held in March, the entries numbered 22,363 as against 22,160 in the corresponding examination last year. For those which commence on May 7th, the entries number 45,888. For the second examination last year, the number was 38,171. In the

Advanced Stage, the total entries for both examinations is 9,282, compared with 9,119 last year. In the Intermediate Stage the totals are 24,467 in 1923, and 21,419 in 1922. The figures for the Elementary Stage are 34,502 this year, and 29,793 in 1922.

The examinations are held in most of the principal cities and towns of Great Britain and Ireland, and in nearly all cases are conducted and supervised by the Local Education Authorities, to whom the Society is greatly indebted for the efficient manner in which these duties are carried out.

There were 335 Centres for the March Examinations, and they will be held at 375 Centres in May. The County of London, where the Examinations are under the control and supervision of the London County Council Education Committee, is only counted as one Centre though it includes entries from a very large number of Evening Institutes, Polytechnics, Proprietary Schools, etc.

The number of entries for the County of London was 1,981 in March, and 14,676 in May.

PROCEEDINGS OF THE SOCIETY.

FOURTEENTH ORDINARY MEETING.

WEDNESDAY, MARCH 7th, 1923.

THE RT. HON. LORD CLINTON, Forestry Commissioner, in the Chair.

THE CHAIRMAN, in introducing the lecturer, said Professor Stebbing had appeared before the Society on former occasions and had always had matters of great interest to place before the Fellows. The subject with which he was about to deal that evening was of the highest importance. The timber forests of Russia had played a large part in the trade of Europe and of the world generally, and the almost total disappearance of the trade connected with those forests at the moment presented a problem which required immediate solution. Any remarks which Professor Stebbing would make upon the subject would be worthy of the very closest attention.

The following paper was read :—

THE FORESTS OF NORTH RUSSIA AND THEIR ECONOMIC IMPORTANCE.

By EDWARD PERCY STEBBING, M.A., F.L.S., Professor of Forestry, University of Edinburgh.

There has never been a period in the history of the world when the study of the political economy of the forest, and its bearing upon the multifarious occupations of mankind has been more imperative. For some time prior to 1914 forebodings of a coming timber famine had been expressed. The Great War with its unprecedented and unexpected enormous demands on the forest focussed, so to speak, a search light on the forest resources of various countries and as one outcome showed up with uncompromising clarity the lamentable deficiency of the British Isles in forestry resources.

At the International Congress of Forestry held in Paris in 1912 the following statistics of the areas of forests in the world were given :—

	acres.
Europe—Total area of forests	786,171,300
Africa—Ditto	753,285,500
America—Ditto	1,616,880,500
Asia—Ditto	965,009,300
Australia—Ditto	236,075,000
Total ..	4,177,421,600

or, approximately, 6,527,000 square miles.

The timbers growing in these forests are for commercial and economic purposes known as soft woods and hardwoods, many of the latter being the so-called luxury woods, as *e.g.*, mahogany, etc. The hardwoods occupy by far the larger area of the world's forests. In spite of this the brunt of the world's present demand for timber falls upon the soft wood forests (pines and firs, etc.), to a section of which this paper is chiefly confined.

The woods in use in this country for commercial purposes belong to both the groups, soft woods and hardwoods. Of these the soft woods formed somewhere about 75% of the wood imports into Britain in 1913. The bulk of the paper pulp imports are also manufactured from the soft woods. As regards their present day geographical distribution the great bulk of the forests of existing soft woods are to be found in Scandinavia, North Russia, Poland, the Baltic States, Finland and North Siberia in the Old World, and North America, Canada and Newfoundland in the New.

The concensus of opinion, both expert American and British, points to the fact that America (United States) has lumbered a very considerable proportion of the enormous forests which existed in that country half a century ago. The Capper Report

and the excellent paper by Sir John Stirling Maxwell in the second number of "Empire Forestry," conclusively show this to be the case. In the near future America will be an importer of soft woods, and especially of that eater of forests, wood pulp. From the geographical position of the two countries it would appear probable that America will indent on Canada for the bulk of the imports she will require, say, during the next half century or so. For any large planting campaign she may initiate would not produce merchantable crops of any importance before that time, if so soon.

Canada has what are still termed inexhaustible forests; though the history of the primæval forests of the world has shown times without number that to no forest area, however extensive, can that term be applied once the hand of man and the activities of man make themselves felt within it. And the rate of exploitation and the demands for material proceed at a faster pace and are increasingly heavy in the twentieth century than they were in the nineteenth.

Although Britain may, therefore, confidently hope to receive a proportion of her requirements in soft woods from Canada during the next 40 years, as a set off she must expect to witness an early cessation of imports from America (United States), and to encounter that country, geographically speaking, in a more favourable situation, as a competitor in the Canadian markets. In 1913, out of a total import of 10,431,309 loads of coniferous timber and pitwood, we received 511,351 loads from America and 897,217 loads from Canada and Newfoundland.

Coming now to the Old World, the history of the soft wood trade is not without interest.

As I have mentioned, the bulk of the accessible forests, so far as Britain is concerned, are situated in the great belt which stretches across Scandinavia, Poland and the Baltic States, and the great tract of forest-covered country in North Russia situated to the north and north-east of Petrograd crossing the Urals and stretching across North Siberia. Another area is found in the Caucasus and the Black Sea littoral from which the Mediterranean markets, to be alluded to shortly, can be supplied.

In the fifties of last century Sweden set out to capture the European, chiefly perhaps the British, timber markets, and Norway followed suit. Up to the beginning of the present century these two countries sent the largest amounts of soft woods to this country. In order to assist this trade Sweden gave large concessions of forest on long leases to timber companies under which by far the larger portion of the forests in the southern half of the country, which were the finest, were cut out, these areas being now chiefly covered by a smaller second growth. The position was much the same in Norway. During the War these countries largely increased their fellings to take advantage of the high prices.

In the northern halves of these countries, and the same applies to Finland to some degree, the forests are mainly under the State Forestry Departments. Here, owing to the more inclement climate the trees are smaller and the growth considerably slower.

In the early years of the present century we find the Scandinavian countries gradually losing pride of place as the chief suppliers to the British markets, that place being taken by Russia, the greater bulk of whose exports to this country at that time came from the Baltic ports.

In 1913, Russia sent us, in round figures, 5,200,000 loads of coniferous timber and pit wood, Sweden 1,759,411 loads and Norway 437,106 loads.

Those who have studied this question find it difficult to believe that the Scandinavian countries, in view of the extensive lumbering to which their forests have been subjected, can maintain their imports to this country at the 1913 figure—that, in fact, by the end of the next decade there will be a considerable diminution. And a Government report published in Sweden during the War foreshadows this position, and expresses the desire that such exports should be fashioned in materials only.

Lastly, we come to the supplies available or likely to be available from Britain herself during the next few decades. In an excellent paper read before this Society by Lord Lovat in December, 1920, he stated that of the 3,000,000 acres of woodland existing before the War probably less than 750,000 acres are fully stocked with "high forest timber," between 15 and 70 years of age. Even assuming that as it becomes mature it will all be marketable at a good price, which we may hope will be the case, it will not go far towards supplying our requirements during the next 40 years.

If this sketch accurately portrays the existing position, it becomes of vital necessity to this country to have some clear conception as to

(1) Where it is going to obtain the supplies of soft woods which, according to past experience, are essential to its various manufactures and industries;

(2) How it is going to obtain these; and

(3) What price it is going to pay for them during the next, say, 40 to 50 years.

As a prelude to a consideration of this vital problem it will be advisable to clear away a few misconceptions of the public who are not in a position to have much acquaintance with this matter. Our requirements, our imports of soft woods are not confined to pit wood for the collieries. Owing to the prominence inevitably given to this article during the War some have appeared to consider that this material is one of the chief ones at issue.

If we omit timber required by the railways and for house construction (which it is held by some can be replaced to a great extent by other materials, and the point may be conceded), of which we use enormous amounts, there are a variety of industries in which, so far, wood is regarded as indispensable. The packing trade, for instance, absorbs vast amounts; and to the book trade and the Press it is at present as indispensable as it is in our own homes, where the articles formed from materials which formerly grew in the forests are innumerable.

What is the present position of the European timber markets, as the result of the World War, and, consequently, what and where are the areas of remaining primæval forests from which they may be supplied during the next forty years?

I may be asked why forty years? The length of the period chosen is admittedly an arbitrary one. It will not suffice to produce timber from the woods of Britain, however expeditiously the Forestry Commission and patriotic private proprietors may be able to proceed with their planting campaigns—nor will it suffice for Sweden, Norway or the United States for the same reason, to obtain a yield from their re-afforested areas. In fact, there is perhaps some justification for hoping that the new forests of Britain will come under exploitation before any of those in the above mentioned countries.

But for reasons I hope to elucidate later, it is essential to take as long a view of this matter as is possible in the economic interests of the community of this country. Such a view cannot be taken by private persons nor by commercial companies unless they have at their back the support, not necessarily financial support, but the support of the Governments concerned.

I am confining myself in this paper to a consideration of the North Russian forests and I trust to be able to show their great importance in this connection. From the study I have made of this problem (it is just twenty years since I first went to Russia with this object in view) I hold that it is from the Northern Russian forests, following the inexorable law of economics, that a considerable proportion of our supplies, and in an increasing amount, must inevitably come. Roughly speaking, the two great European soft wood timber areas or markets are the northern, by way of the North Sea and English Channel, or round the north of Scotland, and the Mediterranean. The Northern markets are supplied chiefly from Scandinavia, France, Germany, the Baltic and the White Sea and these supplies, may, economically speaking, reach the Western Coasts of France, Portugal, and Spain. The Mediterranean market is supplied from the territories of the former Austro-Hungarian Empire, Roumania, the Caucasus, and the Black Sea forests. These materials may also reach the west coast of Spain, Portugal and France. All the Mediterranean countries are supplied with soft woods from these areas as also Palestine, Mesopotamia, Egypt, Turkey, &c. Exports from the North American, Canadian, and Newfoundland forests can supply either the Northern or Mediterranean markets.

From its geographical position, therefore, Britain is mainly interested in what I have called the Northern market and the forests which supply it, as already detailed above. The countries which drew their requirements from the Russian market before the War were Britain, 35.5% of total exports; Germany, 32.7%; Holland, 16.3%; France, 5%; Belgium, 4%; and other Countries 6.5%. We see, therefore, that Britain and Germany took seven-tenths of the Russian exports. We thus find Germany our greatest competitor in the Baltic timber market before the War.

As a result of the war this problem has been greatly complicated by the formation

of the Baltic States and Poland and the appearance of Finland, as independent Kingdoms. In these countries we must expect to find Germany a powerful competitor during the future period I am considering, and in addition we shall have to face a greater competition from Belgium, France and the other countries interested in the Northern markets. The solution of these problems will become, so far as can be estimated at present, increasingly difficult and the competition will result in increasing prices. At least in my judgment the position I have endeavoured to portray appears to be one bristling with possible future difficulties. For it must be remembered that although Poland and the Baltic States have great tracts of as yet untouched soft wood forests, yet we know that great areas, and so far as can be ascertained the more accessible areas, were destroyed during the war—13 million acres it has been estimated. With the increasing prosperity which good Government in these countries may be expected to bring about they will absorb increasingly large amounts of wood for their own industries. Moreover, we may expect to find them adopting the modern economic law of prohibiting the export of timber in the round or in semi-fashioned materials, thus keeping the whole of the conversion in their own countries. This will seriously enhance the cost for the buyer. This was the decision of the Swedish Government in the Report above alluded to, and the Provincial Government in Russia in 1917 was laying down the same procedure; although the main bulk of Russia's timber exports in the round before the War went to Germany, who had sawmills erected on the banks of her side of the Niemen River, and thus only paid for her material in the round.

In 1917 I had an opportunity of studying this question at first hand in Russia from its Russian aspect, and since my departure from that country synchronised with the fall of the Provincial Government and the advent of the Bolsheviks, it may be considered that the information and suggestions that I propose to lay before you are the latest available.

At that period there were two men in Russia, in Petrograd as it happened, who had given this question, and its inevitable issue so far as the future supply of the N. European markets was concerned, a careful study over much the same period of years as I have devoted to it. They had both visited this country in order to obtain first hand knowledge of the methods by which we were obtaining the enormous amounts of material we used in our various industries. Whatever may be said of the Provincial Government which followed the downfall of the Czarist regime on its political side, and the mistakes were obvious to all who gave them any study, the manner in which they were envisaging some of their economic problems, and one of them the exploitation of their untapped northern forests, was eminently sound.

I spent some weeks at the Ministry of Commerce going thoroughly into the matter and making myself acquainted with the proposals and statistics. The bald outcome of their figures and proposals resolved itself into the fact that Russia's first line of rehabilitation after the War would be by means of the exploitation of her forests, chiefly her White Sea forests which cover an area of several hundred million acres; and that with efficient arrangements she would be able to pay her debts and set herself going again in a comparatively short period of years. The area in question comprised the Governments Archangel, Vologda, Olenets, Perm and Viatka. The two former are the most important, comprising between them a total of nearly two hundred million (195,250,000) acres of forest. It was to the forests of the three first mentioned Governments that their proposals were mainly confined.

I would not be understood to say that this was the only work to be taken in hand. Of course, agriculture, once the land question had been settled, was to be restarted, but the officials knew that with the fields gone out of cropping and covered with weeds it would take some time to get this work going again; and a much longer time to restart the industrial centres. The forests were there and work could be started in them, on an annually increasing scale, at once. And this would, of course, assist demobilisation.

I have heard nothing of my friends for three years, and it is difficult to ascertain how much of this work remains on record in Russia. It may perhaps be considered fortunate that we should possess a sufficiently detailed record of it.

Before I detail the measures suggested which, to a great extent, corroborated my own study and views of the problem, though

mine had been arrived at independently, I should like to be allowed to describe a small forest—it comprised 65,000 acres, but still, for Russia, a small forest—Lissinow by name, situated about 60 versts from Petrograd. For British foresters this area is not without interest.

The forest of Lissinow formed one of the areas attached for instructional purposes to the Imperial School of Forestry at Petrograd. But its greater interest was due to the fact that it displayed examples of the four main types of the forests of North Russia under conservative management. An acquaintance with these four types is of importance in connection with the purpose of this address.

These four types are as follows :—

(1) *The Spruce type.*—Spruce is the chief species worked at Lissinow on a rotation of 120 years. The forest is regenerated by making three fellings at intervals of five years during the last 15 years of the rotation, removing a third of the crop each time. If sufficient natural regeneration is not obtained it is assisted by sowing and planting. About six to eight roubles per hectare per annum were obtained from these types.

(2) *Birch and Poplar type.*—Rotation of 60 years. Treatment by removal of one-third of the crop every 20 years. In the latter stages spruce comes in naturally and is finally assisted at Lissinow by sowing and planting so as to obtain mainly a spruce wood. The poplar is always girdled three years before felling so as to kill the sucker shoots. Birch and poplar are only used for firewood, fetching from five to ten roubles the met. cub., birch being 10 times more valuable than poplar.

(3) *Pine type.*—This type is grown on the drained peaty marshes. This is a common type of forest in Russia on the better class of forest soils, the pine forming the predominant species with birch, or birch and spruce, in mixture.

At Lissinow excellent results are obtained by draining the peaty marshes one metre deep at a cost of 10 roubles per hectare. Deeper draining does not give better results. The rotation is 140 years old—worked on a shelter wood natural regeneration system. To start the crop after draining area, the fire the surface and sow with pine and birch seed. The spruce comes in naturally. A fine 50 year old plantation of this type was seen. Sowing the pine and birch together gives better results than the pine alone. There is little wind so birch does not harm the pine. The fine piece of 140-year-old pine of this type shown in the slide was calculated to produce 500 met. cub. per hectare and was valued at 4,000 roubles per hectare. The height of the trees was 93ft. 4in. with a diameter of 17½ inches.

(4) *Pine Type on Deep Peaty Marshes.*—Rotation 80 years. The produce from this type is only used for firewood. It is also regenerated naturally, assisted by artificial planting and sowing.

On drier ground at Lissinow a fine piece of 70-year-old pine and spruce was seen, formed by Arnolt, the Father of Russian Forestry. The turf was pared off and sown with pine seed at 10 kilograms per hectare. The spruce came in naturally.

The cities and towns of North Russia mostly burn wood fuel for heating purposes, birch being the chief species utilised. This is cut in the forests in the winter and brought down the rivers, after the ice has melted, in flat bottomed barges towed by tugs. During the summer of 1917 the Neva and the canals in the Petrograd area were a busy scene ; already, with the dislocation in traffic and labour engendered by the revolution, it had become obvious that but little oil or other fuel from the south would be available during the ensuing winter, and it was becoming evident that wood fuel itself would be short.

To return to the Northern forests. The two Governments which from my study of the question are the most important for the purpose of British supplies of soft woods, are those of Archangel and Vologda. The area of the State forests in the Archangel Government amounts (including the forests formerly owned by the Czar), as computed on 1st January, 1915, to 118,250,000 acres and in the Vologda Government 77,000,000 acres. Of this area 85,250,000 acres are designated as good forest soil in the Archangel, and 76,500,000 acres in the Vologda Government's—this latter is a very high percentage in Russian forests.

The areas which, from information I was given and my own study in the Ministry of Commerce, interested me chiefly for reasons to be described were the districts of Solvichigodsky, Yarensky and Ust Sisolsky in the Government of Vologda ; and these in spite of the difficulties of travel and other troubles which the Revolution had brought about, I was

able to visit, leaving Petrograd in the latter part of August, 1917. My information led me to expect to find magnificent forests in these districts, forests which had been as yet scarcely exploited, and this more especially in the case of Ust Sisolsk. The areas of forests in these three districts are 8,824,000, 15,046,000 and 36,000,000 acres respectively, the proportions of good forest being in the three cases as high as 6,900,000, 14,910,000 and 33,000,000 acres.

I journeyed by train from Petrograd to Archangel via Vologda. From Archangel, which I will discuss later, I proceeded up the N. Dvina by luxurious river boat to Kotlas, some 400 miles up the river. This journey was not without interest, the river being splendidly buoyed all the way up, the buoys being lighted at night. This is rendered necessary owing to the numerous sand banks and shallows which make their appearance with the fall of the rivers in the summer after the melted snow and ice water has run off. Owing to the flat nature of the country, the current of the rivers is very slow and all traffic is undertaken in flat-bottomed barges towed, in a string of 3 to 6, by powerful tugs. The steamers burn wood fuel, and the halts at frequent intervals for taking in fresh loads are useful, permitting a landing and investigation of forestry and other problems.

The Dvina forks into two at Kotlas, the Vichegda, the N.E. branch being the route to the districts above mentioned. Kotlas has undoubted possibilities before it as a commercial centre. It is linked up with Central Russia and the Trans-Siberian Railway by the line running to Viatka. It will also be an important centre on the projected Archangel-Ob Railway. It was startling to see a coal siding here on the river bank—British coal landed at Archangel, brought up the river in barges, whence it was sent by rail to Viatka and Central Russia. There is an alternative route to Kotlas, a river route starting from Kadnikov on the upper waters of the Sukhona River close to the Vologda Railway junction, whence you turn north en route to Archangel. But the passenger is liable to be held up by sand banks if he tries this route in mid-summer. He can, however, return from Kotlas by rail via Viatka and Vologda to Petrograd. These alternative routes are not without their importance in a consideration of the proposals to be dealt with.

All the way up to Kotlas you pass forest on one or both banks, especially after the first 60 miles above Archangel. But it is after leaving Kotlas and proceeding up the Vichegda that you commence to get into the real heavy primæval forest. There is a ribbon of cultivation on either side a few versts broad backed by forest more or less hacked about on its edges for a hundred versts or so, and then the cultivated area strings out in patches attached to small villages, and the illimitable stretch of forests begins, 95 per cent. of which is State forest.

The conditions prevailing in Russia in 1917, and the time at my disposal, did not permit of my making any extensive survey of the forests of the three districts I have mentioned. My object was rather to satisfy myself as to the practical facilities for the extraction and transport of timber cut in these areas, but I was able to make a few excursions, and the standing timber in certain areas is magnificent. The conditions of labour supply and other questions which will readily present themselves to foresters and those conversant with this business were also points upon which I wished to satisfy myself. It became apparent that no insuperable difficulties would be encountered on these heads, the districts being intersected with streams and channels down which, with the melting of the snows and ice, logs could be sent to the main river.

After an hour's run up stream from Kotlas you arrive at the small township of Solvichegodsk, the capital of the district of this name. It numbers 1,500 people and 12 churches, many of them beautiful structures. It was from this town some 200 years ago that the great leader Yerma set out to conquer Siberia. Already up here the people are a semi-forest population and look to the forest to provide them with work and consequently food throughout the long winter. As I have said, the villages in these districts are mostly confined to the strip of cultivation along the rivers. There are none in the great forests. Consequently the contractor engaged in felling the timber has to arrange for all the supplies required by the gangs of labourers he takes up with him to fell the trees and drag them to the water's edge ready for the melting of the snows in spring.

We see up here a very intimate connection between agriculture and forestry, for

assuredly without the winter's work the villagers could not continue to inhabit these regions under modern conditions of life, primitive as they still are in these parts.

The only town of any importance on the Vitchegda below Ust Sisolsk, after leaving Solvichegodsk, is Yarenskuk, capital of the district of Yarensk. This town is situated about a verst from the river bank, contains a population of 15,000 inhabitants, and as is customary, numerous quaint and beautiful churches. A certain amount of work was being undertaken in the forests of this district though but a fringe had as yet been tapped. A small stream, more like a ditch when seen in the summer season with but a trickle of water in it, runs through Yarenskuk into the Vichegda. From 40,000 to 60,000 logs had been sent down this ditch the previous spring when the melting snow filled it. It looked incredible but served as an excellent illustration of the comparatively facile transport advantages in this and the Ust Sisolsky District.

Continuing up stream with the ribbon of cultivation still clinging to the river bank and becoming more and more interrupted by outliers of the great forest belt, we at length come, some 400 miles from Kotlas, to Ust Sisolsk, the capital of the district of that name, which latter has a population of 116,000 or one per 255 acres.

Moxt of the people of the Vichegda basin are Ziryanims, speaking a language or dialect of the same name, which is a mixture of Samoyede and Russian. These Ziryanims are probably the descendants of the first Russian settlers of these parts, who intermarried with the local tribe of Samoyedes and gradually ousted the latter. The Ziryanims have Ust Sisolsk as their chief centre and the country round, for some considerable radius, appears to be entirely inhabited by them and their language the chief one spoken. They are a light-hearted, singing people, fond of bright colours in dress, and very different from the dull, stolid North Russian peasant. They are, as is the case with all the people of these northern regions, expert woodmen.

In addition to its timber wealth the district contains copper, iron, naphtha, coal, mercury, lead and traces of gold. The lead is plentiful; and coal has been worked to a small extent and is of good quality. Capital is required to exploit these minerals and to open out the big forests, which have as yet been scarcely touched.

Up here we get into real touch with the primæval forest which comes down in places to the river bank. The country takes on an undulating character, a pleasing contrast to the dull uniformity seen all the way up from Archangel, and is backed by range upon range of hills to the east, the foot hills of the Urals. The whole countryside is clothed with one great almost pathless forest of pine, spruce and birch, a storehouse from which Western Europe must for some considerable period draw a large proportion of her requirements in soft woods.

It was what I had come to see!—this district which contains nearly 36,000,000 acres of forest, some of it reported by those who were in the best position to know, to contain as fine timber as was to be found anywhere else in Russia.

Already, although but a fringe had been tapped, over half a million logs were floated down the river yearly from Ust Sisolsk, in addition to those brought out down the tributaries between that town and Kotlas.

Felling takes place in winter, the logs being drawn out by ponies over the frozen track to the river edge. They are here made up into rafts and towed down by tugs to Kotlas, and from there to Archangel. Above Ust Sisolsk small rafts only are made and floated down the river to that place. They are then built into the bigger rafts containing 4,000 to 5,000 logs apiece for the tugs. On the smaller tributaries the logs are floated down singly to the larger rivers before being made into rafts. Floating commences as soon as the ice melts and the rivers open for traffic in May. The chief rafting months are June and July from Ust Sisolsk downwards, but the work continues, on a smaller scale, into August and even to the beginning of September.

On arrival at Archangel the rafts are broken up and the logs sawn up in the mills, of which there were some 50 in 1917. Some of these were well fitted with up-to-date frame saws and turned out work of a high grade; others were not so developed. But owing to the inadequate methods of working none before the war turned out more than 60 to 70% of the possible output. This industry was inaugurated in the latter half of last century, and had made some considerable progress by 1914; and one or two of the bigger Baltic firms were transferring their business here. But as is known, the industry was still in its infancy since over

48% of Russia's timber exports went from the Baltic ports.

The chief points requiring consideration at Archangel were connected with the question of new sites for mills and whether it would not be cheaper to erect mills at kotlas. And this did not apply only to sawmills; for I had been giving consideration to the possibilities in front of a wood distillation factory—in which the considerable amount of birch existing in these forests could be utilised, for some of the products of such a factory would command a ready sale in Russia herself. In the series of experiments carried out throughout the war years at the Distillation factory in the Forest of Dean the chemists had ascertained that of all the hardwoods they used there the birch gave the best results. The Russian with whom I discussed the matter of erecting sawmills at Kotlas did not favour the idea saying it would be more expensive to transport the sawn material down the river in barges. This may be correct, but from the conservative way this timber business has been mostly carried on at Archangel, I am by no means convinced upon this point. Rafts and logs also get stranded and held up on the river and this means cessation of the work in the mill. This latter danger would be less if the mills were sitauted at Kotlas with the shorter lead from the forests.

The existing sawmills at Archangel are mostly situated below the town. The ground is low-lying and the terrain is gradually raised by means of refuse, slabs, etc. Several excellent sites for mills were inspected and there appeared to be little difficulty in finding suitable positions for new mills—at any rate for the first comers.

In the actual selection of a site there are several points of imperative importance which would make themselves apparent to experts when inspecting the area, for they have a close connection with working expenses.

No one can visit the new Archangel—for the War made the modern port—without receiving a conviction that a great future lies before it. True, the new Murman Railway is now in existence with the ice-free port of Alexandrovsk at the head of the Kola Peninsula; but this railway, which runs through the Olenets Government on the west, is entirely independent of the Archangel-Petrograd Railway and separated from it by hundreds of miles of desolate *tundra* country. There is no connection between the two and not likely to be for many years to come.

The forests in the Olenets Government contain small trees for the most part, serviceable for wood pulp manufacture. This was one of the directions in which the Russians were proposing to grant concessions, combined with the erection of pulp mills.

I am not proposing to deal in this paper with the forest areas in the Archangel Government which are tapped by the Mezen and the Petchora Rivers. These areas contain fine forests without a doubt, especially the former; but my investigations led me, and lead me still, to consider the region I have described as being preferable.

Having dealt with the position and value of these forests in the Northern Governments of Russia it will be of interest to study the lines upon which the Russian Government was preparing to exploit them according to the proposals drawn up in 1917. These were broadly speaking as follows:—

In order to develop the timber industry and increase the exports from the White Sea forests they considered it would be expedient to—(a) Attract to this industry large capital, both home and foreign. In order to do this in such a sparsely populated country with a lack of communications it would be necessary to offer blocks of forest on long leases on the condition that lessees erected the necessary sawmills and factories and that both large and small material was converted; (b) grant certain facilities to timber merchants who wished to cut in the more accessible districts where the forest was chiefly small and useful for paper pulp manufacture. Leases so granted would entail the erection of pulp factories in the districts worked in. The object of this was to increase the pulp exports and to ensure the fullest exploitation of the forests of the Northern Region; this particular clause had reference to the forests of the northern part of the Olonets Government where the growth is generally of smaller dimensions suitable for this purpose; (c) increase very considerably the output of the White Sea trade in timber by considerably adding to the number of sawmills at Archangel and elsewhere in the region. These would of course automatically follow a commercial exploitation of the great forests; (d) consider th

question of credits to be granted for timber and the opening out of a Northern Bank in Archangel whose object would be to support and develop the timber industry of the north; (e) to endeavour to promote the manufacture of fashioned materials, wood pulp, and so forth in Russia itself; (f) to institute special courses in paper manufacture, etc., and in the higher technical schools and to open lower schools for training the lower technical staffs. It was recognised that this would take time but the ultimate object aimed at in these provisions was to convert the major part of the raw products into fashioned articles in Russia itself and gradually check the export of the raw product or timber in the round or semi-fashioned state.

Finally, a scheme was being worked out for the creation of a northern fleet of timber ships so as to eliminate the fluctuations in freights of foreign tonnage and their dependence upon it. For this purpose the construction of a shipbuilding yard at Archangel was to be commenced. This work would be co-ordinated with the new plans for railway construction in the north *i.e.*, the Archangel-Ob projected railway. As we know, the Allies and principally the British, transformed the port of Archangel by the end of 1917, the place having more than doubled in size in every way since the outbreak of war.

As regards the work of Russia herself in connection with the forests of this region, the following plans and rules were to be put in force as soon as the end of the War made their introduction possible:—

(1) Full investigation within a few years by the Forestry Department of all the State forests of the five northern Governments, Archangel, Vologda, Olenets, Viatka and Perm.

(2) To work out a plan of a network of wood roads for extracting the timber and for improving the floating capabilities of the rivers and streams in the forest districts, and to arrange for obtaining the necessary funds for the purpose.

(3) To draw up similar plans for the drainage of marshy forest districts.

(4) Whilst encouraging the increased exploitation of the forest to commence the working of the immense reserves of peat existing in the State forests.

(5) To organise a timber agency abroad which should assist the working of both the State Forest Department and private timber industries and trades.

(6) To construct several Government saw mills in the North in order to obtain a better knowledge of foreign market prices by sending materials from these mills to the markets and by selling their produce direct to the Governments of Allied and neutral countries.

(7) To increase considerably the number of foresters and the local administrative staffs, also the strength of the forest guards, and to improve the prospects of the staff.

(8) To open a middle school of forestry in Archangel in order to constitute a permanent staff of local forestry workers, and to open several lower forestry schools in the provinces.

It was also remarked that in order that the full development of the exploitation work of the Northern forests should prove successful, a programme of measures in connection with the solution of local land problems, colonization, and the development of agriculture should be drawn up and carried out with continuity.

I discussed these various proposals in detail with the officials of the Ministry of Commerce and the representatives of the Forest Department. Their conclusions followed much on the same lines as those I had arrived at independently. The matter was being widely discussed in the Russian press at the period, and there was a concensus of opinion that the proposals were sound. There is no idea of interfering in any way with the existing saw mills at Archangel, of which there were about 50. Their pre-war output, however, was put at about 60-70 per cent. only of their capacity. These would carry on their work. But the exploitation of the forests on the large scale would require a much greater effort and more up-to-date methods.

The project discussed between myself and the official representatives was the following. It had been decided at the Ministry that concessions of forest should be allotted to applicants, each block to contain 50,000 hectares (125,000 acres). The block was to be the unit and any Government or private party to be allowed to take up several blocks if they so wished. These concessions were to be granted in the Governments of Archangel, Vologda and Olenets. One or more saw mills and pulp mills would be erected by the concession holder in suitable situations, the

material to be converted before export in accordance with the Government decision in force at the time. Such transport works, roads, improvement of river beds etc., as might be required to be constructed by the concession holder. The contract to be given for 20—25 years. As regards an arrangement with Britain, the total area to be so granted was not fixed, but it was suggested, subject to confirmation, that a minimum area of State forest of 500,000 hectares (*i.e.*, 1,250,000 acres) might be allotted to be worked by British capital. An additional area might be ear-marked in N. Siberia. There were other details worked out which, in the altered conditions of Russia since that date, it is unnecessary to deal with. But I may add that the matter was gone into in a very thorough manner. My main contention was that the term for which the concession was allotted should be at least 35 years, and I wished it to be 40. This point was left over for future discussion, should steps be actually taken to obtain a concession. I may add that in a communication sent to me in February, 1918, the period was raised to 40 years. The other factor of importance was the question of guarantees of non-disturbance. It was agreed that the steps to obtain a concession should be taken by the two Governments, and that, agreement come to, the capital should be found and the concession worked by private enterprise, should this be the desire of the British Government. From the outset I had never envisaged the British Treasury having to take any part in the transaction.

It was pointed out to me by my friends, with considerable insistence on many occasions, that the British would have to be wary and act with decision when the moment came if they wished to secure the best concessions. There were numerous Swedes, Norwegians and other foreigners in Petrograd in 1917 straining every nerve to obtain concessions. For the most part I was told that these were the representatives of the big timber companies of Scandinavia who having cut, during the past half-century, all the forest on the concessions they had obtained in their own country wished now to secure similar ones in Russia, and thus be in a position to carry on their exports to Britain and other countries in the north European markets; we to pay the extra prices which success on their part in this direction would entail. But even more important to my view was the fact that some of the forests in which concessions to work would be given were so situated that extraction and transport would cost the minimum, whilst others would entail higher charges for this work. For this reason I marked down on the map, with my friend's help, areas which I deemed the most suitable for our purpose.

I shall be asked, What is your suggestion? Have you a concrete proposal to make?

As far back as March, 1915, in a paper read before this Society, I first drew attention to the importance of the Russian forests in connection with our timber supplies. In their Final Report (May, 1917), the Forestry Sub-Committee of the Reconstruction Committee, in reviewing the future supplies of soft woods available to Great Britain, stated that "Russia is now the crux of the whole question."

My proposal is the same now as the one I put in Petrograd in 1917 to a prominent British timber merchant and owner of forests in Russia, whose father had been in the same business in Russia all his life. The former was then doing war work at the British Embassy. Just before I left Petrograd I gave him a general outline of my matured opinion.

My proposal was that a big British combine should be formed, that it should be financed to such an amount as might seem desirable to start with, that a concession of 2½ million acres of forest in this northern region should be obtained on a 40 year lease, and that the undertaking should be subsequently financed as it developed. That saw mills should be erected at Archangel or at Kotlas, or perhaps at both centres after a careful investigation on the spot. That a distillation factory might subsequently be erected at Kotlas, owing to its favourable situation for the distribution of the products. That a pulp mill might be set up in the Olenets Government forests from which the pulp could be despatched from the Murman railway port. That, finally, in order to reduce freight charges the combine should gradually build a fleet of timber vessels, as had, in fact been the idea of the Russian officials.

The scheme fired his imagination. "It would be the biggest thing done in this way in Russia," he exclaimed, "and it is possible, and I know the business or ought to."

There can be little doubt that, started on the correct lines, it would be a paying

investment alike to the capitalists, to Russia herself, and as important, in my view, to our country in the future, since it would help to remove a future source of trouble and anxiety, whilst, at the same time enabling us to maintain some influence on the market prices of timber and pulp wood.

This was the position at the end of 1917 so far as these Northern Russian forests are concerned. It remains the position to-day—with a difference, that the larger portion of the forests whose materials were shipped from the Baltic ports before the war now belong to several autonomous States separated from Russia. The position of the forests in these latter States is by no means clear at the present nor can it be foreseen with any certainty what it will be during the next 40 years. For instance, Poland up to recently had decided to work her forest areas through the State Forest Department. How far she will depart from this policy is not at present apparent. Moreover, under the new conditions it will be necessary to make separate arrangements with each State, and this will entail separate establishments, mills, etc., and higher costs all round, which ultimately fall upon the consumer. By working on a large scale from one centre costs are reduced, profits increased, and the article cheapened for the consumer.

Having studied the question for so many years before the war and having regarded it from the new conditions which the war has brought about, it appears incumbent upon me, it appears a duty to place the matter in as clear a light as possible before the country, with the hope that adequate steps will be taken before it is too late. In the present state of Russia with its trade totally dislocated, the greater part of its rich agricultural land gone out of cropping, with its industries ruined for the time being, there is little room for doubt that when the day of rehabilitation, of commencing the work of rehabilitation, dawns, this work will start, will be the most easily started, in its great untapped forest regions. The demand for soft woods amongst many European countries and in America is greater now than possibly it has ever been in the history of the world. Amongst the countries of Europe, Britain is for the greater part dependent on imports of these products. If we allow that she can obtain 50%, or even 60%, of the imports from her own woods, from Sweden and Norway, and from Poland and the Baltic States and from Canada, where will she obtain the remainder? It is probable that even the amounts so obtained will dwindle before the 40 year period has lapsed.

It appears to me inevitable that a very considerable proportion of her requirements during this period, and in increasing amounts, will come from the White Sea Ports.

I suggest that we should endeavour to obtain three areas—

(1) Half a million acres in the Olenets Government to be worked for pulp wood.

(2) One million or one-and-a-half million acres in the Vologda Government.

(3) One million acres in the Ob Forest area to the East of the Urals in Northern Siberia.

I believe it will prove feasible—I had almost said, it is feasible (for the opportunity might arrive at any moment) to arrange for such concessions in the forests of this region from which these supplies can be procured, the cost to us being the royalty to Russia, plus the cost of extraction and transport to Britain. This will give our industries the material they require at a cheaper rate.

In my opinion, this matter has now become of paramount importance. We cannot afford to remain quiescent.

If we fail to take this step in time we shall have to repeat the policy of the past and buy our requirements from the foreigner who may secure the concessions; for the working of these great forests—in the present condition of Russia this matter is now a certainty—must be undertaken by the foreigner. If we do not take the opportunity offered we shall have to add the middleman's prices, the foreigners' profits, on to the price we have to pay for the timber.

This is the conviction my study of this question has forced upon me, and in the interests of our country and its industries it appears to me to be one which demands early consideration and decisive action.

DISCUSSION.

THE CHAIRMAN, in opening the discussion, said the author had dealt with matters of supreme importance to the trade of this country. He had shown the importance of Russia to the trade of the world. In passing, he (the Chairman) would like to express the hope, which he thought all present felt, that the time might come when Russia might be freed from the misfortunes which had followed her during the last half dozen years; and it was quite possible that that

freedom might come from the development of her great resources in timber. The importance of Russia to this country in the timber trade was evidenced from the figures which the author had given. Thirty five per cent. of the whole bulk of the Russian trade came to this country. For the moment that was entirely lost. But, apart, from the immediate effect of the loss of that Russian trade, the author had dwelt, very rightly indeed, upon the larger question, namely, the probable shortage of a world timber supply in the immediate future. The demand for coniferous timber had been increasing at a very rapid rate indeed. Substitutes for timber, which technical experts in the world were always finding, were very frequently referred to, but in spite of the fact that during the last one hundred years wood had been replaced by various metals, actually the number of cubic feet per head of the known population of the world was always annually increasing. It was useless, therefore, to look forward to any substitute which would take the place of that really great soft wood demand which was being experienced all over the world. The author had referred to what used to be termed the "inexhaustible" supply of timber on the American Continent. The supply had never been inexhaustible. The only thing that was inexhaustible was the demand, and it was quickly overtaking the supply. One of the great causes of the increased demand for timber was the necessity of the manufacture of paper pulp. It was rather humiliating, he thought, to those who knew the great work of Nature in the magnificent forests on the Pacific Coast, to find that those finest sights in the world of timber should gradually be transforming themselves into news print, which sometimes adorned, but more frequently disfigured, the country. The great exporting country of the United States could now scarcely supply herself, and her demands were reaching the British Empire. The natural market, unfortunately, for the bulk of the Canadian timber was the Western States of the United States, and, with the opening of the Panama Canal, a demand was being experienced even from the Eastern States. Europe could no longer depend, for any great period of years at all events, upon a continuous supply from the Canadian Dominions. Professor Stebbing had told his audience of the vast area of forests of the world. He (the Chairman) believed that 1,200,000,000 acres was about the acreage of timber in the British Empire. He did not know exactly what that meant. He did not know whether those millions of acres were covered by marketable timber; whether they were completely covered with timber, or whether all the timber was accessible. That was perhaps one of the important features of timber-covered land, namely, whether it was accessible to markets. He was quite certain that figures of timber acreage always conveyed to one's mind a greater amount of timber than actually existed. There were no real statistics available. Even in this country the knowledge of our small quantity was very scanty indeed. It was known that we had roughly 3,000,000 acres, but we had a very small idea of what they could produce for our uses in this country. The Forestry Commission at the present moment had a scheme on foot, and were already operating it, to get out a statistical survey, which would, he hoped, add to the present available information. And on a somewhat larger scale the Forestry Commission were taking part in an Imperial Conference in Canada during the summer, which would give some idea of the timber resources of the whole Empire. It was quite certain that we should have to conserve our timber resources, and increase them, if the position was not to get really serious. The Home Government three years ago, after half a century of persuasion, had started on a forestry policy of their own. It had been only in force two years before the serious demand of economy in this country made it necessary for the Government to curtail their operations; but although the operations had been curtailed, it was, on the whole, satisfactory to know that they continued to exist, and that England and Scotland were making some efforrts, at all events, to provide for the scarcity which might occur in the future.

The author had dealt in the last sentence of his paper with the possibility of the exploitation of the great timber resources of Russia. There was no doubt whatever that almost every nation in the world was looking after that timber and endeavouring, when the opportunity arose, to make some arrangements with a Russian Government to obtain that timber for world uses. It was impossible, after merely hearing the paper, to express an opinion on the financial side of the question, but it was quite certain that it was essential to trade development that those resources should be exploited, and it was, on the face of it at all events, a good opportunity for the investment of British capital, which in that way could be used, not only, one hoped, to the profit of the investor, but to the profit of the trading world.

Mr. R. L. Robinson (Forestry Commission) said he had listened with very great pleasure to the paper, the more so because Professor Stebbing had talked about a part of the world in regard to which it was very difficult to get any information at all. His Department were trying to collect together statistics of what timber there was, and when it was likely to get on to the market. In regard to most countries, they could either send a man to gather that information or they could get fairly reliable local knowledge. In the case of Russia, however, as things were at present, they had to be content with what news adventurous people, like the

author, had been able to bring back. Although he professed to have no particular knowledge of the area under discussion, it did not require very much specific knowledge to be able to recognise at once that the northern part of Russia was going to be a tremendous factor in the timber supply and pulp wood supply of the United Kingdom. The problem of where this country was going to get its timber and its pulp wood was a difficult one. At the best, the North American Continent, which used to supply us with a great deal of timber, at no very distant time would not be able to look after itself with regard to its timber and wood pulp supply, and it was not unlikely that on occasions that Continent might even have to come to northern Europe to compete with this country, Germany and others for supplies of timber and pulp. As a matter of fact, he believed the Americans had already been in the Scandinavian market for pulp wood. What he would like would be to hear from people who had local knowledge of the particular region under discussion, what area of forest there was there, what proportion of it was marketable and accessible, and what sort of stand there was per acre.

MR. CHARLES GANE said he had known Russia for twenty-five years intimately, and on one occasion he had made a most interesting journey through some of the districts which the lecturer had shown on the screen. He had then an opportunity of seeing the forests of Northern Russia as Professor Stebbing had described them, and he had been very much impressed indeed with them. It might be of interest to those who were associated with Russian timber to know what was being done at the present moment. It was his business, for his sins, to keep himself in pretty close touch with the ideas of the Soviet Government with regard to their forests and so on. At present the condition of Russia was pitiable, and it was really heart-breaking to hear the conditions under which the Russian people were now working. One captain of a boat had told him that the condition of the labourers was so appalling that they could scarcely stagger along carrying a deal or scantling to the ship. They had practically no food; their clothing consisted of sacks with holes in them and their feet were swathed in rags or straw. During the present year various fantastic figures had been published as to what the Soviet Government believed they would export from the White Sea and from Petrograd; they talked of 400,000 standards, which would be 1,200,000 loads. That, he thought, was impossible. It was only fair to the Soviet Government to say that they were trying to evolve some system of forestry and of developing their wood export trade. Their present system was to plot out the country into districts. They had formed companies—some of which were registered in this country and one or two in Holland—in regard to which they had adopted the American principle of fifty-fifty; that was to say, the Soviet Government took 50 per cent. of the profits and the other 50 per cent. went to those who were putting up the capital and carrying on the business. In that way it was only fair to say that they were now attracting back to Russia a certain number of men skilled in the wood trade, and unquestionably some attempt would be made—with what success he could not say—again to develop the wood industries. He supposed it was not an exaggeration to say that the forests in Russia were not producing to-day more than 10 per cent. of what they produced before the war. It was lamentable; but he quite agreed with the author that it was chiefly to North Russia that we should have to look for our supplies again. At present the outlook was by no means cheerful, and it would take years, he thought, before the wood business would be re-established on a sound basis again in Russia.

With regard to the scheme which the author had in mind, and which was an admirable one, the difficulty was for anybody now to put money into Russia. London was besieged with requests for capital, but everybody was afraid—perhaps wrongly—to put money into Russia under the present system of Government, which included no proper Courts of Justice to whom merchants could go for redress if necessary. Until the Soviet Government could set up something which would safeguard the sanctity of contract it would be a very long time before the exports of wood from Russia would flow again with their pre-war smoothness.

On the motion of the Chairman, a hearty vote of thanks was then accorded to the author for his paper.

PROFESSOR STEBBING, in reply, said in connection with the remark which had been made—that it would be a very long time before the North Russian forests were again exploited—his own opinion was directly contrary to that. He had left Russia in 1917 with what had been practically an offer to the effect that the Government were prepared to welcome British Capital in those northern forests, and were prepared to give concessions for very considerable areas to British firms to work those forests; but the proviso had been made that an arrangement must be come to between the Russian Government and the British Government. So far as one could forsee, that arrangment would probably have materialised in 1918 if the Bolsheviks had not upset the Provisional Government. Five years had passed since then, but Russia was a country in some respects like India. He had had some considerable experience in India, and he thought there was a parallel

to be drawn between those two countries. Both had very large uneducated populations, and it was generally found in countries like those that no matter what catastrophes might occur, they recovered infinitely more quickly than people in the West could conceive. Given a guarantee between the two Governments, he did not see why the work should not be started in Northern Russia in the next couple of years. There were men in this country who were fully conversant with the whole business and capable of taking it up to-morrow. He saw no difficulty in getting capital. The one thing was to initiate an arrangement between the Governments. It would be the country who got in first which would get the best of those areas, —best, he meant, in the sense of being most accessible, and therefore capable of being worked with a minimum of labour. There were areas which would involve the minimum of cost to work, but there were areas at the back where the work was going to be much more expensive. He would therefore like to convert his audience into thinking that big concessions might be obtained at any moment. At all events, other nations were looking that way, and Great Britain might get left.

NOTES ON BOOKS.

A Text Book on Heat and Heat Engines, By Andrew Jamieson. Vol. II. Eighteenth Edition. Re-written by Ewart S. Andrews. With numerous diagrams, folding plates, and examination questions. London: Charles Griffin and Company, 1923. 8*s*. 6*d*. net.

Opening the volume at p. 234, we see a reproduction of an old sketch showing the steam turbine of Hero of Alexandria, and in this engine we have a generic or type picture of all steam engines and of all internal combustion engines.

The jet or nozzle is the homologue of the piston, while the massed air opposite the jet is, by virtue of its inertia, the homologue of the cylinder-end; the surrounding air is the homologue of the cylinder itself.

Next in order and in well illustrated sequence, the student is guided in a detailed study of stages in progress by which the waste of heat is lessened, as in the Laval hundred-horse-power turbine (p. 253), the Brush-Parsons turbine (p. 272) and as a climax we have a tabulation of the great turbine ships now in service on the Atlantic.

Although a turbine may receive its energy as an even or constant tangential strain or torque, such a condition is impossible in the case of a piston-and-cylinder engine; as here is involved a repeated sequence or cycle of thermo-dynamic conditions which may be expressed quantitatively by a diagram, and such sequences or cycles are explained and illustrated from p. 8 to p. 69. Afterwards, we have a partly similar study of the principles involved in reversed heat-engines (refrigerating machines). Compressed air conditions and chimney draft data are followed by well considered and well illustrated descriptions of the more important internal combustion engines, and many mechanical details incident to heat engines.

Thus we have a work which embodies full and reliable details as to the range covered; it is obvious, however, that a main aim of the book is to be of service to those preparing for engineering examinations, but it is evident that the authors have been somewhat embarrassed by the various senses in which words are used in examination papers.

Uncertainty seems to centre largely on the word efficiency, as three aspects of efficiency appear to be involved in question 7, and two aspects in question 8 on page 417; but reference to the text of the work rather increases the difficulty. In the preface, thermo-dynamic efficiency, also practical and economic efficiency are touched upon, but so lightly as not to help the student very materially. Again, on p. 2 we find indicated efficiency and brake efficiency contrasted, and this with some measure of success, but on the same page we read of maximum efficiency, maximum possible efficiency and mechanical efficiency; while the paragraph on p. 3, headed "Scientific and Commercial Efficiency," seems calculated to add to the difficulties of a student who may attempt to formulate an answer to so complex a question as No. 8, on p. 409. On p. 292, it is set forth that "it is essential that the word efficiency should be clearly defined," but as the result of an unsuccessful effort to define, we read of one more form, "net efficiency" (p. 293, l. 2.). There is no doubt that some or many wastages incidental to the operation of heat engines may be defined and measured, but the complementary concept, non-wastage, does not seem to come into such clear view, and seems rather to defy summation; this mainly by the multitude of conditions leading to efficiency, and the consequent sorts and aspects of efficiency.

CORRESPONDENCE.

COLOUR: CHARTED AND CATALOGUED.

With reference to the notice of my book, "Colour: Charted and Catalogued," in the *Journal* of March 9th, may I point out that there is a numerical notation, as each of the 400 hues has a distinctive consecutive number? The critic says, "If the author had devised a purely arbitrary series of names—or devised a numerical notation, the work would have been invaluable."

This number provides an alternative reference to a hue, for those who prefer a number to a name. I gave much thought to the subject of nomenclature and decided that for general use, names from natural objects were the most suitable. The application of trade names varies among different firms, but anyone using the charts could call a particular hue saxe blue or any other name that was wished. Perhaps it might be possible to get a consensus of expert opinion in order to affix more suitable names in some cases.

E. Fellowes.

KAOLIN DEPOSITS IN CHINA.

While clay in its ordinary form is widely distributed throughout the world, the purest form—kaolin—is restricted in its occurrence in large quantities. In the United States, for instance, the relatively few known deposits of commercial value are for the most part in the Southern States, although California, Colorado, Nevada and Vermont have important deposits and are producers of kaolin. Most of the kaolin imported into the United States comes from England, but in view of the great increase in the price of this clay since 1913 the United States Trade Commissioner in China has drawn attention, in a report to his Government, to the sources of supply in China of this product.

So far as is known, the Chinese first made porcelain during the Han dynasty, from 210 B.C. to 220 A.D. In 1004 A.D. the Emperor King Teh established the Imperial potteries at a place in the Province of Kiangsi, south of the city of Kiukiang, on the Yangtze River, which received the name of King Teh Chen, and has ever since remained the chief centre of the ceramic industry of China. In the earlier centuries only white and coloured porcelains were made; then about 1268 A.D. decorative painting of porcelain was introduced. In recent years potters of this district have begun to produce foreign styles of porcelains. There are reported to be somewhere around 150,000 potters employed. The clay from which the porcelain is made is, according to von Richthoven, a high-grade sedimentary clay.

The next porcelain centre of renown is Te Hua, in the interior of the Province of Fukien, 50 miles due west of the coast city of Hing Wah. This centre has specialised largely in white porcelain statuettes, with other articles in white or with blue patterns, but has gone more recently into the production of foreign-style porcelain painted in various colours. Te Hua uses a high grade of kaolin which occurs in great quantity in the immediate vicinity.

The third pottery centre is Shekwan, near Canton, in the Province of Kwangtung. This is a comparatively new centre, the industry having been established there about 700 years ago. The highest grades of porcelain are not made in Shekwan proper, but are produced in Kochow, a small town in the same district. High-grade clays obtained in this locality are chiefly used, but it is stated that some kaolin is brought in. For a long time foreign shapes have been made there for the export market.

The best grades of porcelains are manufactured at the above three places, but ordinary pottery is made practically all over China, and in travelling in the interior one frequently passes through local pottery centres where earthenware bowls, teapots, vases, cuspidors, etc., are produced. All of the most important plants in which the highest grade wares are made and which use the best grades of clay and kaolin are situated in southern China in the great area south of the Yangtze River. In many respects this area is comparable with the area embraced in the Southern States of the United States, especially as regards temperature and rainfall—the important factors which influence the alteration of the rocks from which kaolin is produced. South China is more favoured than the southern part of the United States in the wide distribution of the types of original rocks from which kaolin is derived and in the occurrence of large deposits of the clay.

The high-grade porcelains are made from kaolin obtained within short distances of the pottery centres, but none of these kaolin deposits are conveniently situated for export. Transportation has not been in the past an important factor in the minds of the Chinese. The Chinese industries, especially the pottery industry, are the result of the gradual growth of centuries, starting with the object of supplying purely local needs. No consideration was paid in the first instance to factors other than the known occurrence of the raw material and the local market, the factor of transportation being negligible under these circumstances. Thus the output from the kilns at Te Hua is carried by porters in baskets, two balanced on a shoulder pole, distances ranging up to 100 miles to market.

In modern practice, the economic assemblage of raw materials for the product to be made and the ease of reaching the best markets are thoroughly considered before the location of the manufacturing plant is decided upon. A detailed study of the kaolin deposits of China will, it seems quite certain, result in the finding of deposits more favourably situated to supply the markets of to-day than those now utilised in the ancient centres. In the interior of the Province of Fukien, especially, there are several undeveloped kaolin deposits which appear promising in size and quality, and doubtless a search would disclose others more favourably situated with respect to transportation than are these.

The most favourably situated Chinese deposit of kaolin so far reported, which could serve as a source of supply for the foreign market, is in the Province of Kwangtung, and as there is

no pottery industry in this vicinity the exploitation of the field should meet with hearty local co-operation, since it would offer continuous employment for a number of people otherwise dependent entirely upon the intermittent local agricultural demand for labour.

The Chinese ceramic industry, although 2,000 years old, is still essentially in the same condition as it was many centuries ago. It is lacking in organisation; and, although it is claimed that the Chinese invented the potter's wheel, no other advance has been made, and the industry is still a household one, using primitive kilns and antiquated methods. The Chinese Government and also the Province of Kiangsi support a ceramic laboratory, but so far as can be learned no definite effort has yet been made anywhere to develop the industry on a large-scale factory basis following modern methods of production. Nevertheless, China's exports of clay wares to foreign countries were one and three-fourths times the value of the gross imports in 1918, three and a half times in 1919, and nearly six times in 1920.

GENERAL NOTES.

PROFESSOR A. A. MICHELSON'S INTERFEROMETER AND ANTARES.—In 1920 the Albert Medal of the Royal Society of Arts was presented to Professor Albert Abraham Michelson, For. Mem. R.S., for his optical inventions, which render possible the reproduction of accurate metric standards and measurements with a minute precision hitherto unobtainable. Professor Michelson's wonderful interferometer was recently installed on the 100-in. Hooker telescope at the Mount Wilson Observatory, California, and steps were taken to ascertain the actual diameter of the first magnitude star Antares. It is announced that the resulting figure is approximately 420,000,000 miles.

WORKING OF SOAPSTONE DEPOSIT IN ONTARIO.—An announcement has been made of the organisation, with a capital of 500,000 dollars (about £100,000), and with head offices at Toronto, of a company to mine soapstone in the Wabigoon district, about 200 miles north-west of Fort William, Ontario. The company is said to own one of the largest soapstone deposits known, which upon exploitation will not only supply the Canadian demand, but provide a surplus for export. The development of the industry, writes the United States Consul at Fort William, will be of interest to the pulp and paper companies which use this stone for lining kraft-mill furnaces and pulp digesters. Soapstone is also used extensively in the electrical, rubber goods and other industries.

TESTS OF TASMANIAN TIMBERS FOR PULP PRODUCTION.—An important series of tests on the possibilities of using certain Tasmanian timbers for the manufacture of paper pulp has just been completed by the Institute of Science and Industry, and favourable results are reported. The tests were made at the Geelong mill of the Australian Paper & Pulp Co., and the timbers were treated by the modified chemical process, which has been found particularly suitable for Australian woods. A high yield of pulp of excellent quality was obtained, which, after an admixture of about 30 per cent. of foreign pulp, makes a high-grade printing paper. The results obtained at the Geelong mills, reports the United States Trade Commissioner at Melbourne, completely reverse previous verdicts by American and English experts that Tasmanian timbers were commercially useless for paper-making purposes. It is claimed that the cost of treatment by the chemical process adopted at Geelong is less than that used abroad for the production of a similar grade of pulp, and that from information at present available the total cost of production at certain points is likely to fall below that for which pulp can be imported from abroad.

MEETINGS OF THE SOCIETY

ORDINARY MEETINGS.

Wednesdays at 8 p.m., except where otherwise stated:—

MAY 9.—WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Surface Combustion, with special reference to recent Developments in Radiophragm Heating." D. MILNE WATSON, M.A., LL.B., Governor of the Gas Light and Coal Company, will preside.

MAY 16.—L. GASTER, "Industrial Lighting and the Prevention of Accidents." SIR MALCOLM DELEVINGNE, K.C.B., Assistant Under-Secretary of State, Home Office, will preside.

MAY 30 (at 4 p.m.).—A. J. SEWELL, "The History and Development of the Perambulator and Invalid Carriage."

INDIAN SECTION.

Friday afternoons.

JUNE 1, at 4.30 p.m.—AUSTIN KENDALL, I.C.S., rtd., "The Indian Section of the British Empire Exhibition, 1924."

JUNE 15, at 4.30 p.m.—SIR JOHN H. MARSHALL, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India,

"The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture.)

Howard Lectures.

Monday evenings at 8 o'clock.

Stanley S. Cook, B.A., M.I.N.A., M.I.M. (Parsons Marine Steam Turbine Co.), "The Development of the Steam Turbine." Three Lectures. April 30, May 7, 14.

Syllabus.

Lecture II.—The introduction of mechanical gearing. Other types of gearing. Application of mechanical gearing to large powers in Naval Vessels. Development of the mercantile marine turbine. Comparison of modern and early efficiencies. Whirling of rotors. Lubrication and pivotted thrust blocks. Methods of attaching blades. End tightened reaction blading. Land Turbines: various types. Progress in economy and output. The problem of the exhaust area.

Lecture III.—Application of mechanical gearing to land turbines. Geared turbines for mill driving. "Pass out" turbines. Geared turbo generators. Direct coupled turbo alternators. Non-salient pole rotors. Ventilation of stators. Latest improvements in economy of turbines by re-heating and cascade feed-heating.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

Monday, May 7 .. Geographical Society, 135, New Bond Street, W., 8.30 p.m. Mr. F. K. Ward, "The Thibetan Border—Yangtse to Irawaddy."

University of London, Physics Department, Imperial College of Science, South Kensington S.W., 5.15 p.m. Professor W. de Sitter, "Problems of Fundamental Astronomy."

At King's College, Strand, W.C., 5.30 p.m. Prof. R. Dyboski, "Outlines of Polish History." (Lecture II.)

At King's College for Women, 61, Campden Hill Road, W., 4.30 p.m. Professor V. H. Mottram, "Nutrition." (Lecture II.)

Royal Institution, Albemarle Street, W., 5 p.m. Monthly meeting.

Surveyor's Institution, 12, Great George Street, S.W., 8 p.m. Mr. C. H. Bedells, "Some Functions of a Surveyor under the Settled Land Acts, 1882-90, and Part 2 of the Law of Property Act, 1922."

Tuesday, May 8 .. University of London, University College, Gower Street, W.C., 5 p.m. Dr. H. R. Kruyt, "The Electric Charge of Colloids."

At Bedford College for Women, York Gate, Regent's Park, N.W., 5 p.m. Prof. Abel Le Franc, "La Littérature Française au XVIe Siècle d'apres les plus récents Travaux." (Lecture I.). (In French.)

Royal Institution, Albemarle Street, W., 3 p.m. Prof. A. C. Seward, "Ice and Flowers of Greenland."

Colonial Institute, Hotel Victoria, Northumberland Avenue, W.C., 8.30 p.m.

Petroleum Technologists, Institution of, at The Royal Society of Arts, John Street, Adelphi, W.C., 5.30 p.m. Mr. W. A. Guthrie, "Heavy Grade Egyptian Crude Petroleum."

Wednesday, May 9 .. University of London, University College, Gower Street, W.C., 5.15 p.m. Sir Thomas Holland, "Phases of Indian Geology." (Lecture I.) 5.30 p.m. Prof. H. S. Foxwell, "The History of Currency and Banking."

At King's College, Strand, W.C., 5.30 p.m. Dr. E. Barker, "Ethics and the Philosophy of History," by the late Prof. D. E. Troeltach. (Lecture III.)

5.30 p.m. Prof. P. Geyl, "Dutch Architecture in the XVIth and XVIIth Centuries." (Lecture II.)

At Bedford College for Women, York Gate, Regent's Park, N.W., 5 p.m. Prof. A. Lefranc, "La Littérature Française au XVIe Siècle d'apres les plus récent Travaux."

At King's College for Women, 61, Campden Hill Road, W., 4.30 p.m. Prof. V. H. Mottram, "Nutrition." (Lecture III.)

Literature, Royal Society of, 2 Bloomsbury Square, W.C., 5.15 p.m., Professor J. Drinkwater, "The Poetry of Alice Meynell."

Thursday, May 10 .. University of London, University College, Gower Street, W.C. 5.15 p.m. Prof. E. G. de Montmorency, "Customary French Law." (Lecture III.)

At King's College, Strand, W.C., 5.30 p.m. Principal L. P. Jacks, "Reality in Religion and in Education." 5.30 p.m., Dr. O. Vocadlo, "Czechoslovakia." (Lecture I.)

Royal Institution, Albemarle Street, W., 3 p.m. Prof. J. T. MacGregor-Morris, "Modern Electric Lamps." (Lecture III.)

Royal Society, Burlington House, Piccadilly, W., 4.30 p.m.

Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C., 6 p.m. Dr. J. A. Fleming, "Problems in Telephony, Solved and Unsolved." (Kelvin Lecture.)

Historical Society, 22, Russell Square, W.C., 5 p.m. Sir C. H. Firth, "The Portraits of British Historians in the National Portrait Gallery."

Optical Society, Imperial College of Science, South Kensington, S.W., 7.30 p.m. Dr. J. W. French, "Stereoscopy Re-stated."

Chemical Society, at the Institution of Mechanical Engineers, Storey's Gate, S.W., 8 p.m. Prof. W. H. Perkin, "Baeyer Memorial Lecture."

Central Asian Society, at the Royal United Service Institution, Whitehall, S.W., 5 p.m.

Friday, May 11 .. Engineering Inspection, Institution of, at The Royal Society of Arts, John Street, Adelphi, W.C., 7.30 p.m. Mr. H. J. Davey, "Some Notes on Ciment fondu—A Cement of High Initial Resistance —with results of Chemical Analysis," by Mr. H. F. Knight.

University of London, at Bedford College for Women, York Gate, Regent's Park, N.W., 5 p.m. Prof. A. Lefranc, "La Littérature Française au XVIe Siècle d'apres les plus récents Travaux." (Lecture III.)

At the School of Oriental Studies, Finsbury Circus, E.C., 5 p.m. Dr. P. Giles, "The Aryans." (Lecture I.)

At King's College, Strand, W.C., 5 p.m. Mr. W. Macnab, "Some Scientific Principles of Chemical Indsutry." (Lecture I.)

5.30 p.m. (Shakespeare Association). Sir Sidney Lee, "A Survey of First Folios."

Royal Institution, Albemarle Street, W., 9 p.m. Prof. W. H. Bone, "Gaseous Combustion at High Pressures."

Japan Society, 20, Hanover Square, W., 5 p.m. Prof. H. Hishinuma, "Main Features of the Japanese Problem."

Astronomical Society, Burlington House, Piccadilly, W., 5 p.m.

Malacological Society, at the Linnean Society, Burlington House, Piccadilly, W.

Physical Society, Imperial College of Science, South Kensington, S.W., 5 p.m.

Saturday, May 12 .. Royal Institution, Albemarle Street, W., 3 p.m. Mr. J. B. McEwen, "Dance Music."

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FRIDAY, MAY 11, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.,

NOTICES.

NEXT WEEK.

MONDAY, MAY 14th, at 8 p.m. (Howard Lecture.) STANLEY S. COOK, B.A., M.I.N.A., M.I.M. (Parsons Marine Turbine Co.), "The Development of the Steam Turbine." (Lecture III.)

WEDNESDAY, MAY 16th, at 8 p.m. (Ordinary Meeting.) L. GASTER, "Industrial Lighting and the Prevention of Accidents." SIR MALCOLM DELEVINGNE, K.C.B., Assistant Under-Secretary of State, Home Office, will preside.

HOWARD LECTURE.

On Monday evening, May 7th, MR. STANLEY S. COOK, B.A., M.I.N.A., M.I.M. (Parsons Marine Turbine Co.), delivered the second lecture of his course on "The Development of the Steam Turbine."

The lectures will be published in the *Journal* during the Summer Recess.

DEATH OF MR. MAURICE DRAKE.

Following the announcement of the postponement of the Ordinary Meeting on May 2nd, Fellows of the Society will learn with much regret of the death of Mr. Maurice Drake, who had undertaken to read a paper on that date on "The Fourteenth Century Revolution in Glass Painting." Mr. Drake was taken ill just after he had started to prepare his paper, and he died of pneumonia at Exeter on April 29th.

PROCEEDINGS OF THE SOCIETY.

FIFTEENTH ORDINARY MEETING.

WEDNESDAY, MARCH 14TH, 1923.

LORD ASKWITH, K.C.B., K.C., D.C.L., (Chairman of the Council), in the Chair.

THE CHAIRMAN, in introducing the lecturer, said Sir William Mackenzie was the Chairman appointed under the Industrial Courts Act, 1919, and had had a very wide experience indeed of industrial arbitration both in the course of, and since, the War. As an acknowledged expert in this country upon the subject, and as a man with a very wide acquaintance with industry, the audience would hear what Sir William had to say with great interest, and they might take it that he spoke with very great authority.

The following paper was read:—

INDUSTRIAL ARBITRATION.

By SIR WILLIAM MACKENZIE, K.B.E., K.C., President of the Industrial Court.

It is a thought-provoking reflection that Industrial Arbitration is still regarded by many persons as a novelty and a somewhat doubtful experiment. Those who take this view, which I think is mistaken, are not necessarily anarchists or persons holding wild and revolutionary political opinions. They consist for the most part of substantial and respectable employers, sober and conservative-minded trade unionists and others who would never dream of settling such differences as arise between them and their fellowmen by other than peaceable means. If a dispute occurs between two business men, no matter how vitally their interests may be affected, or how great the sum at issue may be, it becomes a matter of perfectly courteous discussion between their legal advisers, and, in the event of failure to agree, is submitted, as a matter of course, to a tribunal which sits with decorum and cold aloofness and gives in the end a decision by which they are required to abide. I do not believe that in the twentieth century people follow this course merely because it is prescribed by law; they do it because it is sensible. To allow the hundreds of disputes which daily occupy the ordinary courts of this country to be settled by a trial of strength between the parties would send us straight back to the dark ages; it would end in confusion; and it would produce results which no one

would pretend were just or equitable. Yet methods which would be looked upon as barbarous for the purpose of settling business differences in general are too often accepted as a matter of course and even of economic necessity when a business difference of a particular kind occurs, that is, a difference between an employer and his workpeople as to rates of pay and conditions of service; and respectable citizens who abhor the idea of physical force see nothing outrageous in a difference of this character being settled by the grim weapons of the strike or lock-out.

I have stated the position in somewhat vigorous terms, not because I am unmindful of the great difficulties in the way of making a sudden break with tradition, but because I think that, however slow progress may be, the first necessity is that, to use the Platonic metaphor, our eyes should be turned to the light and no longer absorbed in the mere shadows on the cave. We must occasionally, in thought at least, break the heavy shackles of tradition and conventional points of view and get a clear and philosophic sense of our position at the moment and of the direction in which we wish to travel. Thereafter we may move slowly—the inertia of human institutions is enormous—but we shall move surely and we shall move straight.

It is with some hope of inspiring a sense of direction that I have attempted in this paper to plot out, as the statisticians say, the historical curve of industrial arbitration and to show, by way of reassurance to those who believe that nothing is good unless it is ancient, that neither in its main conception nor in the details of its practice is industrial arbitration a wind flower of post-war optimism. Its roots are buried deep in much thought, discussion and experiment in times past and it remains for us, if we are conscious of the inconsistency and anomaly to which I have already alluded, to nurture a promising plant and to encourage its rapid growth by such human means as are available to us.

Early Legislative Efforts.

For the purpose of our enquiry we need not go back to the Statute of Labourers of the time of Edward III., or to the judicial method of settling wages established by the Statute of Elizabeth, or to the Statute of James I., under which minimum rates of pay were fixed by Justices of the Peace—the forerunner of the Trade Board. These provisions had their place and their day.

It will be sufficient to begin with the year 1747. In that year appears the first symptom of the modern idea of arbitration, when, by an Act of Parliament, Justices of the Peace were given jurisdiction over disputes between employers and workpeople arising during the currency of a hiring.

In 1800, we come to a real stage of industrial arbitration, when a Bill was passed "for settling disputes that may arise between masters and workmen engaged in the cotton manufacture in that part of Great Britain called England." The reasons which led up to this Bill might have been heard any time during the last eight years. They are set out in a petition to the House of Commons, in 1800, from the cotton weavers in Cheshire, Yorkshire, Lancashire and Derbyshire. This country had been at war with France since 1793. Trade was dislocated, the cost of living was increasing and wages were being reduced. There was no system of adjusting wages (by the grant of war advances or war bonuses) to the altered conditions caused by the increase in the cost of living, which was so marked a feature in this country during the recent War. The weavers complained in their petition that they had been greatly injured for a series of years past by the reductions of their wages and other oppressions year after year, from the year 1792 to the present time, although the price of provisions had borne no proportion to such reduction but, on the contrary, had been progressively increasing during that period; and that these oppressions had been brought about by a powerful combination of the master weavers and manufacturers, and had created divers differences and disputes between the masters and workmen to the great injury of both parties and of the trade; and that the petitioners scarcely earned a bare subsistence, and were totally unable to seek the suppression of combinations of so much secrecy, wealth and power, or any redress of their grievances by any existing law; and they urged that it would be a great convenience and advantage to all parties concerned, and an encouragement to the manufacture, if a more speedy and summary mode than the present were established for the general regulation of abuses in the trade which were of a nature that could not be corrected by any existing law, and for the settling of the wages, pay and price of labour therein from time to time as occasion should require.

The manufacturers likewise lodged a petition for a Bill. They did not notice the point urged in the operatives' petition about the reduction of wages, but they alleged that all persons engaged in the trade had for some years past laboured under considerable difficulties and suffered many inconveniences owing to there being no power under any existing law of properly and promptly settling and regulating the wages, pay and price of labour of the operatives.

The Act of 1800 was accordingly passed. It set up machinery of a detailed character which, in the event of the employers and workmen being unable to agree respecting the price for work done and to be done, gave either party power to demand arbitration. Each side was empowered to appoint an arbitrator, and the award of such arbitrators was to be final and conclusive between parties. Should the arbitrators be unable to agree, the points in difference were to be submitted to a Justice of the Peace in the locality, whose decision, to be given "within the space of three days," was to be final. It is interesting to note that this early statute gave to the arbitrators power of summoning witnesses and examining them upon oath.

So satisfied was Parliament with this piece of legislation that in the same session it passed another Act in similar terms, making the arbitration proceedings applicable to all trades and industries, but so that the jam and the pill might go together, the Act also contained a code of provisions against what were termed unlawful combinations of workmen for raising wages.

In 1803, an Act on similar lines was applied to the cotton trade in Scotland.

The Acts of 1800 were apparently not a success. Those engaged in the cotton manufacture complained that the Act (39 & 40 Geo. III. c. 90) had been in great measure defeated, and a Committee of the House of Commons reported that the power given by the Act to employers and workmen to nominate persons to hear and determine disputes had been productive of great inconvenience and delay.

In 1804, the Act of 1800 was accordingly amended by providing a new procedure whereby, if the parties to the difference agreed to abide by the decision of a Justice of the Peace he might decide it; but if not, he was to nominate a panel of four or six persons—one half masters and one half operatives—and from this panel the parties were to choose one person each to act as arbitrators. If the two arbitrators failed to agree, the Justice of the Peace was to decide. The payment of £10 by the defaulting party to the other was the sanction for the performance of the award.

In 1813, an Act introduced into the cotton trade in Ireland a similar method of deciding disputes by referees appointed by a Justice of the Peace.

Thus, by 1813, there were statutory provisions for industrial arbitration in force in England, Scotland and Ireland.

The hand-loom weavers were greatly dissatisfied with the turn the working of these arbitration proceedings had taken, and, despairing of any remedial legislation, they appealed to Quarter Sessions to have their wages assessed under the Act of Elizabeth. The only result was that the subject once more came under the notice of Parliament, and the Government of the day repealed this part of the Act of Elizabeth, on the ground that it had fallen into desuetude, and the principle of the Act was condemned by the exponents of the fashionable political economy of that day.

In 1824, the law was consolidated and the previous legislation amended. The Bill was prepared by three members well known in their day and still remembered for their interest in social affairs—Mr. Hume, Mr. Sturges Bourne and Mr. Peter Moore. The Justices of the Peace of Liverpool petitioned against the Bill. The new Act introduced a system of referring disputes primarily to referees appointed by a Justice of the Peace or finally to a Justice of the Peace. The disputes capable of being thus referred are defined by the general words "disputes arising out of or touching the particular trade or manufacture or contracts relative thereto which cannot be otherwise mutually adjusted and settled," but there followed an important limitation—that future rates of wages could not be fixed "unless with the mutual consent of both master and workmen." Either party could demand arbitration.

The Act was amended in 1837, but it had not proved satisfactory, and it was now about to receive its *quietus*. In 1838, a mechanic at Kelso had been convicted under the Act and sent to gaol on the complaint of his employer, and the conviction caused no little agitation in industrial

centres. A petition was lodged in the House of Commons to alter or repeal that part of the Act. The Act was, in fact, becoming discredited. It was afterwards amended in one or two details, but the amendments failed to restore the confidence of the workpeople.

In the "fifties" the question of providing means of conciliation and arbitration was much discussed. A Committee of the House of Commons sat in 1856 to "enquire into the expediency of establishing equitable tribunals for the amicable adjustment of differences between master and operatives." Following on this enquiry, Mr. Mackinnon, in 1859, introduced a Bill to establish courts of conciliation, which sought to provide a system of voluntary arbitration, but the Bill was not passed.

Efforts by the Parties.

Let us now leave the Parliamentary stage and see what is being done outside. Gradually since the failure of the Act of 1824, various trades had endeavoured independently to establish reasonable means of settling differences. In the pottery industry arbitration was frequently resorted to from 1836. Carpet weaving, the printing trade, the Macclesfield silk trade, the Cheshire salt trade and the Birmingham wire trade are among early examples of the application of the methods of conciliation and arbitration. In the Glasgow pottery trade and the Glasgow tailoring trade, the workmen were bound by a rule of their Unions to refer all disputes to arbitration, and the report of the Pottery Union for the year 1860 states that the clause in their Rules had often been put into operation, and had been successful in 90 cases out of 100.

From this period the principle appears to have made fairly steady progress, the number of trades setting up boards for the mutual discussion of points of difference, and the reference, if necessary, of the matters at issue to arbitration constantly increasing.

Further Legislative Efforts.

A new champion of industrial arbitration now enters the field in the person of Lord St. Leonards, the great real property lawyer, and a former Lord Chancellor. In 1860 he introduces a Bill for the setting up of Councils of Conciliation to settle industrial differences, but the Bill was introduced only for the purpose of discussion and consideration. For five years he keeps in touch with employers and workpeople. At first the employers are rather taken with the idea and the workpeople are not. In 1865, thinking the time about ripe, he again introduces his Bill, once more only for discussion. In 1866, he introduces it again, but meanwhile the employers are becoming lukewarm, and the workpeople keen supporters; so again he drops it. In 1867 he introduces the Bill for the fourth time. It had been reported favourably on by a Select Committee, and the Law Lords had minutely examined its clauses. Lord St. Leonards was certain that if Councils of Conciliation were established there could be no doubt they would be freely resorted to and their action would tend both to prevent and arrange disputes. The decisions pronounced by those tribunals would have judicial form and could be enforceable by law. A hundred thousand operatives in the building trades in the Metropolis supported the Bill. There were petitions in favour of the Bill from employers in the building trade, and from every description of labour in that trade in Birmingham, Manchester, Stockport, Blackburn, Coventry and other large manufacturing towns. The Bill was also approved by delegates from various trades that would be affected by it. The time now appeared ripe, and Lord St. Leonards pressed the Bill forward. There was one matter on which both employers and workpeople were in particular agreed—that the Bill should empower the Councils of Conciliation to deal with future wages. Lord St. Leonards was opposed to the idea, for how could you compel an employer to pay a wage which his business might not be able to bear or a workman to accept a rate which he was not willing to work for? However, as both parties wished it, he would make provision, which he did, and inserted a period of twelve months. In due course the Bill came on in the House of Lords. The Duke of Argyll supported it, and Lord Shaftesbury expressed his approval. Lord Cranworth, another ex-Lord Chancellor, objected to the proposal about fixing future wages. For, said he, with legal acumen, if the parties were not bound to remain with each other for twelve months, the order would be nugatory; and if they were, such a regulation might be attended with injurious consequences. In vain did Lord St. Leonards plead that the provision was desired by both employers and workpeople. Four days later a division

was taken. The debate had not been exciting, nor was the House crowded. There were ten lords present: nine voted for the deletion of the twelve months and one for its retention. Thus Lord St. Leonards lost the day by eight votes. The Bill, as thus amended, rapidly passed through the House of Commons, and became law in 1867. It provided for the past and the present, but not for the future. The machinery set up was somewhat complicated. The Act authorised employers and workmen in any trade or occupation to form themselves into Councils of Conciliation on obtaining a licence from the Crown; a Council would consist of not less than two employers and two workmen and a chairman; and the awards made by the Councils might be enforced in the same way as the award under the Act of 1824, that is, by distress, sale and imprisonment.

Unfortunately, the Act of 1867 became a dead letter. No licence was ever applied for and no Council ever set up, and Lord St. Leonards's assiduous propaganda extending over seven years was lost: no, not entirely lost; for his Act appears to have formed the basis of a statute of the State of New York in 1886; but the New York Statute was not very successful, for very few boards were ever appointed under it.

In 1869 a Committee of Trade Unions recommended a Court of Arbitration, but that it should be voluntary. Mr. Mundella prepared a Bill to carry out this recommendation, and in 1872 it was introduced into the House of Lords. Mr. Mundella had already done yeoman service in promoting arbitration and conciliation in his own trade (hosiery) at Nottingham. Lord Kinnaird was the sponsor of Mr. Mundella's new Bill, and was a sanguine supporter. He firmly believed that if their Lordships passed the measure it would tend to put an end to strikes. The Bill passed both Houses without further discussion. This Act enabled the contracting parties to bind themselves as to every class of dispute (including future wages) to be settled by arbitration. Its intention was to extend the Act of 1824 in such a way as to obtain a different form of tribunal and to enforce the decisions arrived at.

The Act was never put into force, and, like the Act of 1867, became a dead letter. Nothing further was done by way of legislation until 1896.

Further Efforts by the Parties.

Once more the various trades had to fall back on themselves. The machinery set up by their initiative, sometimes called Conciliation Boards, showed differences in detail, but was of a uniform general type. Its essential feature was that trade difficulties should be discussed, in the first instance, by those who were best qualified to discuss them, that is to say, the employers and workers concerned, each party to the dispute having equal representation. In the event of failure to agree, the matter was referred to referees or an arbitrator chosen according to some agreed plan. These arrangements were for the most part short-lived. They seemed to want some central authority to give them life. There are, however, one or two notable exceptions.

The iron and steel trades have, perhaps, the oldest and best equipped system of voluntary industrial arbitration of any trade or industry. In 1869, as the result of a disastrous strike, the Board of Arbitration and Conciliation for the manufactured iron and steel trades of the North of England was established. Similar boards in the industry were established in other parts of England, Scotland and Wales. Eventually, by a process of amalgamation of the constituent bodies, one special system of arbitration is recognised in the trade. The matter in difference is first investigated by a neutral committee consisting of representative employers and employees in equal numbers and on the neutral committee failing to agree, the matter may be referred to arbitration. It is the proud boast of Mr. John Hodge, M.P., the President of the Confederation of Iron and Steel Trades, that the Board has for upwards of 30 years eliminated strikes and lock-outs from their industry. The boot and shoe trade has developed a similar method of dealing with its industrial differences, a characteristic of it being the requirement of financial guarantees consisting of the deposit of sums of money by employers and workpeople in the hands of trustees to secure the due carrying out of agreements and awards.

Passing over a series of years, we come to a new departure made in the Railway Industry in 1920. The railways were then under Government control, and the Ministry of Transport and the National Union of Railwaymen and the Associated Society of Locomotive Engineers and Firemen voluntarily formed a National Wages Board

to deal with all labour questions affecting those employees of the Railway Companies who were employed on the traffic side, as distinct from those employed in Railway Workshops. This Board acted at a very critical stage with remarkable success, and the Railways Act of 1921 expressly affirms and continues the appointment of the National Wages Board. The Board, under the Act, consists of six representatives from the Railways, six representatives from the Unions (the National Union of Railwaymen, the Associated Society of Locomotive Engineers and Firemen and the Railway Clerks' Association) and four representatives of users of railways and an independent chairman appointed by the Minister of Labour. The Board is really an appellate tribunal from the Central Wages Board, which is composed of an equal number of representatives from the railway management and the three railway Unions, and before whom come all general questions affecting the employees in the first instance. The Board is still in its infancy, but from the success that has hitherto attended its efforts, its future seems to be assured, and it is an interesting form of an arbitration tribunal.

Why Previous Legislation Failed.

Let us pause for a moment to enquire why it was that the legislation of the 19th century down to the year 1896 was a failure. There was certainly a strong desire on the part of the employers and workpeople that some satisfactory provision should be made by the Legislature for Industrial Arbitration, and doubtless there was an honest desire on the part of the Legislature to supply such a provision. The diagnosis was sound, but the prescription was defective. We have already seen wherein the measures prior to 1824 failed. A Committee of the House of Commons in 1856 attributed the failure of the Act of 1824 to three causes—dislike to appear before a Justice of the Peace, the reluctance to place the decision in the hands of newly-appointed and untried arbitrators, and the suspicion attaching to the Justice of a manufacturing district in the eyes of the operatives of belonging to a class unsympathetic to them. A fourth cause might be added—that the penalties for non-observance—distress, sale and imprisonment—were too severe. The Act of 1867 refused the very relief which the parties were anxious to obtain—power to deal with disputes relating to wages to be paid in the future. And in the case of it and the Act of 1872, employers and workmen hesitated to incur the liability to a rigid enforcement of Awards that might not only be unsatisfactory, but in some cases impossible of fulfilment.

The simple expedient of giving the award of an arbitration tribunal the same validity—no more and no less—and the same liability for non-observance, as in the case of an agreement arrived at between the parties, does not appear to have occurred to any one.

Next, it may be asked: "Why weary us with all this archaic legislative effort which was, when not a dead-letter, a failure"? The answer is that the history of the past, well considered, is the foundation for the future. The résumé shows, for example, that compulsory industrial arbitration is, in this country, impracticable and the discussions on the Industrial Courts Bill in 1919 confirm this view. It further shows that a penal sanction on the non-observance of an award is also impracticable. The parties may agree to a penal sanction on non-observance as in the case of the boot and shoe trade. But the question of imposing a sanction as a part of statutory arbitration is really, at the present time, academic rather than practical, for it is to be observed that, out of several hundreds of awards issued by the Industrial Court, only three or four have not been observed, and some of these were not rejected, but were eventually accepted subject to modification. The *résumé* also shows, I think, that Industrial Arbitration is not at once to become the complete substitute for the strike and lock-out. The tradition of the strike and lock-out has so long prevailed that Industrial Arbitration will take some time, even under the new methods—of which presently—to justify itself.

Conciliation Act: Lord Askwith.

Let us now resume. In and prior to 1891 there had again taken place a series of strikes and lock-outs, and attention was called to State action as a means of prevention or settlement of labour disputes. With a view to investigating the whole question once more, a Royal Commission was appointed in 1891 to enquire into various questions affecting the relations between employers and workmen, and to report whether legislation could, with advantage, be directed to the remedy of any faults

that might be disclosed. The Commission sat for nearly four years, and its results are published in 19 folio volumes and form a mine of industrial lore. While the Commission was still sitting, Mr. Mundella, who was now President of the Board of Trade, again introduced, in 1891, a Bill for settling industrial disputes but it failed to pass. After the Commission had reported, another Bill, substantially on the lines of Mr. Mundella's Bill and adopting certain recommendations of the Commission, became law in 1896. This Act enabled the Government to do very little that it was not previously in its power to do before the passing of the measure, but its great advantage was that it gave a particular Government Department, namely, the Board of Trade, a definite duty towards and relationship with the movement in the direction of the peaceful settlement of industrial disputes. The Board of Trade could, if not as a right, certainly as a duty, inquire into the cause and circumstances of any existing or apprehended difference, and, on the application of one of the parties interested, appoint a person to act as conciliator, or, on the application of both parties, appoint an arbitrator. The Act served a useful purpose and the Department of the Board of Trade concerned in its administration reached especially under Sir George (now Lord) Askwith, a position of great importance and influence. All elements of compulsion had at last been removed from the provision thus made by Parliament for dealing with industrial disputes. If a conciliator was appointed either party, or both parties, could ignore him; they could refuse to arbitrate, and if they submitted their differences to arbitration they could set aside the award after notice without fear of legal consequences. The importance which the measure attained, and the action taken under its authority must be largely ascribed to the vigour and ability of Lord Askwith. The first operations under the Act were not very happy. One or two unfortunate episodes occurred shortly after the Act was passed, which drew a considerable amount of disrepute on the Act and on the Board of Trade. Fortunately, for the sake of industrial peace, Sir George Askwith was appointed in 1909 Comptroller-General of the Commercial, Labour and Statistical Department of the Board of Trade, and, in 1911, Chief Industrial Commissioner, whose duty it was to administer the Act. He soon restored the Act to its proper place, and the Act became, under his fostering care, an important means of settling industrial differences. The importance of the measure and the action taken under its authority are not to be estimated by the mere figures of the number of cases in which there was intervention. Judged by war and post-war experience, those figures were modest enough. In 1898, 12 cases were dealt with; in 1899, 11 cases. The greatest number in any one year was 99 in 1913. In retrospect we see that the important consequence of the Act was that under it a corner, albeit a small corner, of a Government Department became interested in and concerned with industrial disputes as a matter of official duty, and what I may call the art of conciliation and arbitration began to develop. It became some one's "job" to take a hand, from an impartial standpoint and with the authority of the Government behind him, in a dispute which was involving loss and public inconvenience; and the public became not only accustomed to intervention, but expectant of it. Very warily did the officials of those days need to tread. The Trade Unions were finding their strength and were not always docile under the process of official suggestions and advice. On the other hand, collective bargaining was a new and abhorrent idea to many employers. The employer to-day who will not have dealings with Trade Unions is regarded in the nature of a pre-historic survival and occasions public amusement rather than sympathy. But how rapidly events have, in fact, moved is best brought home by our reminding ourselves that the railway strike of 1911 was due to the refusal of the Railway Companies to recognise the men's union.

Certain Labour men were called in to help with this new function of Government, chief of whom were the late Mr. John Burnett, Mr. Haig Mitchell and Mr. D. C. Cummings, and excellent was the service they rendered. Certain officials without Labour antecedents must certainly share the credit for what prestige came to attach to the old Labour Department of the Board of Trade. Prominent among them were Sir George Askwith and Mr. H. J. Wilson, now the Permanent Secretary to the Ministry of Labour.

In 1911, an Industrial Council, consisting of 13 representatives of employers, 13 repre-

sentatives of workers and Sir George Askwith as Chairman, was established by the Board of Trade. Another series of industrial disturbances was then in progress. The Council included Industrial Arbitration among its functions, but its principal purpose appears to have been to ventilate the rights and wrongs of any dispute of major importance. The representative members were all actively engaged as officials of employers' and workmen's organisations. It was in any case too large to act as an administrative tribunal; and although it was agreed at the first meeting that members should treat matters "as if they were acting in a judicial capacity and not as advocates," it was rather a large demand to make upon their powers of detachment, engaged as they otherwise were as protagonists on the side of employers and workmen respectively, and selected as they were because of that fact. Whatever hopes centred upon the new body appear to have been disappointed. Its inherent defects for the purpose of both conciliation and arbitration soon became manifest and, save for a valuable report on Industrial Agreements, it never achieved any result of importance. It appears to have been appointed for a period which was renewed once, and on the expiration of the extended period, there being no further renewal, the Council ceased.

War Period: Committee on Production.

I do not propose to deal in detail with the War period. That would mean tracing our way through the maze of the Munitions of War Acts. A brief summary is all that is necessary, as experience has, I think, shown that, contrary to what was commonly believed, war legislation in respect to labour was a mere episode, and not the beginning of a new development.

But I should like to premise what I have to say about the War period with this remark: that the years of work before the war proved that strikes and lock-outs could be adjusted, and this alone made possible the remarkable system of conciliation and arbitration adopted and adhered to by employers and workpeople during the War, and that without this, and the confidence obtained by such prior work—in spite of interference, setbacks and spasmodic disturbances—there would have been chaos; and that this was in the main due to the Department of which Lord Askwith was the head.

During the War, the individual rights of both workmen and employers were curtailed; and the corollary was that, through prior agreement between workmen and employers, rates of wages were largely fixed either by Departmental Order or by compulsory arbitration. The principal arbitration tribunal was the Committee on Production.

The irrelevancy of its name is explained by the fact that it was originally designed for purposes different from that which it came afterwards to serve. During the War, after its inception in 1915, the Committee on Production heard nearly 4,000 cases. Not only did it determine the rates of wages in a very large number of trades, some, such as engineering and ship-building, of the first importance and magnitude, but its decisions were watched and followed by many other trades, so that it exercised a very real influence on the wages level in industry generally.

The Whitley Committee.

The importance of the Committee on Production, and the familiarity of its proceedings at Old Palace Yard, Westminster, to employers and Trade Union leaders, were, doubtless, responsible for the opinion that came to be held that when the War period had passed, some permanent and continuing arbitration tribunal should be established. If we exclude the recommendation of the Committee of Trade Unions in 1869, the suggestion was first made authoritatively by the Whitley Committee on the Relations between Employers and Employed. Under the recommendations of that Committee, a standing arbitration Court was to form part of the whole structure of negotiating machinery of which the well-known Whitley Councils or Joint Industrial Councils also form part. The Whitley Committee has, in fact, determined the present system of conciliation and arbitration, and its recommendation may, therefore, be shortly reviewed.

The Committee started from the assumption that all parties in industry desired to live in amity and concord; and that, where this desire was frustrated, it was due largely to want of knowledge and understanding. Shop Committees were to soften relationships between individual employers and their workpeople; District Councils were to provide the means of discussion between groups of employers and workpeople in the districts in which, as a matter

of tradition, a certain local sentiment prevailed; the Joint Industrial Council was to be the assembly of selected representative employers and workpeople in the whole industry. All the Councils and Committees were to be formed on the principle of equal representation to both sides. There were to be no outsiders, so that, in the event of a deadlock occurring, there were no means of relieving it from the inside. Some appellate and impartial tribunal, to which in the last resort a difference could be taken, thus became necessary as the apex of the scheme, and was, in fact, recommended.

There are now between 60 and 70 Joint Industrial Councils actually functioning; and although they are not all equally successful, the experiment as a whole, from the point of view of the maintenance of industrial peace, may fairly be said to have justified itself.

The best conception of the value of the Joint Industrial Councils may, perhaps, be obtained by comparing them with the Conciliation Boards, whose history, as we have seen, goes back to the early 19th century. The Conciliation Board was a joint body of employers and workers, which dealt with disputes and nothing else. Generally speaking, its task was not to prevent differences but to heal them. It met when relations had become very strained. Moreover, its meetings were infrequent; and we can ask ourselves whether the conditions are favourable to success, in the case of a body meeting only when feeling is inflamed, and consisting, for the most part, of persons who never meet together except at such times. The Conciliation Boards were an excellent institution, and had succeeded in settling many disputes, but the weakness which I have pointed out was real enough, and it is to the credit of the Whitley Committee that they perceived it. The Committee were aided in their analysis of the position by what had happened in the case of Trade Boards. Trade Boards were first set up in this country by Mr. Churchill in 1910, for the purpose of regulating wages in trades which enjoyed a bad reputation for paying low rates. The Boards were continuing bodies, and, incidentally to their main business of fixing minimum rates, they were required to meet with some frequency for administrative and practically non-contentious business. According to Mr. G. T. Reid, formerly Secretary to the Trade Boards, a friendly spirit prevailed among the employers' and workers' representatives. If another person agrees with you, even though it is about something which is not very important, he immediately goes up in your opinion. And when, later, the real tussle comes, the mutual respect which has grown up is of great importance. Moreover, at the crisis, when differences have become acute, there comes into play a sense of loyalty to the body of which we are members, a reluctance to smash it up or to break from it.

Under the recommendation of the Whitley Council, the Joint Industrial Councils and the other subordinate bodies forming part of the scheme were, therefore, to have a much wider range of interest than the old Conciliation Boards. They were to meet regularly; they were to consider many matters relating to their trades: measures for regularising production and employment; the collection of statistics and information; the improvement of the health conditions obtaining in the industry; and so on—not only, as I apprehend, because the consideration of these matters might *per se* prove profitable or beneficial to the trade, but because joint endeavour in respect to such subjects, over which violent passions were not likely to be aroused, would contribute to the formation of a tone and temper which would bring the ship safely to port when a real storm blew.

The Joint Industrial Councils lie beyond the immediate concern of the Government. The Ministry of Labour promotes and helps with their formation, watches over them to some extent, and keeps in touch with their work. But apart from this, they are self-governing institutions and can, if they choose, keep all outsiders, whether official or otherwise, at a distance. The fact that they exist entirely on a trade basis may in time show itself to be a danger. The Joint Industrial Council presupposes a high degree of organisation on the part of both employers and workers; and some of us may occasionally remind ourselves of the remark of Adam Smith that "people of the same trade seldom meet together, even for merriment and diversion, but the conversation ends in some conspiracy against the public or on some contrivance to raise prices." Signs of the evil have appeared; but it would not be just to overstress them,

and the matter is one in respect to which watchfulness rather than alarm is appropriate.

I have dealt at some length with Joint Industrial Councils, which are, perhaps, not entirely pertinent to the subject of this paper, but I wish to emphasise the point that discussion between the parties should, as a rule, precede arbitration, and the procedure of the Joint Industrial Council gives an opportunity for such discussion.

It would conduce to a false view of the situation if I conveyed the impression that the field of industry was in any sense fully covered by Joint Industrial Councils. Such is not by any means the case: the majority of trades, including the majority of workpeople, still rely on direct negotiation, either side approaching the other when anything is demanded, or proceeding through neutral committees, as in the case of the iron and steel trades, or through a National Board, as in the case of the traffic side of the railways. The sphere of usefulness of the Department (now part of the Ministry of Labour) concerned with keeping the industrial peace has not been sensibly restricted. To judge from the more elaborate organisation and larger staff of the Department, the contrary has occurred. Local conciliation officers have been appointed, in addition to more highly placed men at headquarters. When a dispute occurs, or is apprehended, therefore, an official is soon in touch with the parties and endeavours, with whatever tact he possesses and the occasion requires, to bring about a peaceful settlement. According to Departmental practice, the first aim is to bring the parties into agreement: if this fails, arbitration is as a rule suggested.

Panels of Arbitrators.

Some care in the selection of arbitrators was, no doubt, exercised under the schemes set up by various trades independently of legislation but the first notable step towards the recognition of a class of persons possessing special qualifications to act as arbitrators, was in 1908 the compilation of panels by the Board of Trade, under the Conciliation Act of 1896. An arbitration tribunal at that time might be one of two types. It might consist of a single person, presumed to be impartial; or it might consist of such impartial person, together with other persons, balanced in numbers, who could be presumed to be specially capable of representing the points of view of employers and workers respectively. Three panels were accordingly formed: an employers' panel; a workers' panel; and a panel of impartial persons or chairmen. The chairmen's panel, or those members of it that had cases referred to them from time to time, may be said to have formed a class of professional arbitrators. They were, however, men with other and more compelling interests, and an occasional arbitration was a mere interruption of such interests. There was, moreover, no provision by which they were to be kept in touch with one another, and no facilities by which they could formulate and adopt common standards. The result was that the awards issued conformed to no particular principles; they were disconnected fragments; carefully impartial as a rule, but representing nothing more than what, in each case, seemed to the individual arbitrator to be the most expedient way out of the difficulty in the particular case confronting him.

The Industrial Court.

The experience of the Committee on Production as a standing arbitration tribunal appeared to show the advantages of coordination in determining differences. The arbitrators employed upon their task day after day could not afford to be unmindful of the effects of a decision upon parties not immediately before them, for to-morrow those parties might appear and would not be slow in pressing any advantages to be derived from a precedent of the Court's own setting. In short, a standing court is practically compelled, for its own reputation, to adopt Kant's maxim of acting only on the principle that can be applied universally. The possibility and desirability of adopting universal principles in arbitration is a matter to which I shall recur; but at any rate the Whitley Committee assumed an affirmative decision on both points, and in recommending arbitration as the final solvent of industrial dead-locks they reported, as I have said, in favour of a permanent court.

It was Sir Robert Horne, as Minister of Labour, who, in his Industrial Courts Act of 1919, gave effect to this part of the Committee's recommendation and to the successful work of the Committee on Production and its immediate successor, the Interim Court of Arbitration. The Act

sets up a permanent Court, consisting for the most part of full time persons, whose duty it is to determine industrial differences and nothing else. To some extent the Act may be said to lack the courage of its convictions, because the Industrial Court is set up, not instead of, but in addition to, pre-existing machinery, so that it is still possible to set up tribunals or appoint arbitrators specially for particular cases. Parties desiring arbitration cannot, therefore, complain that the Act confines their choice of authority. The Act also makes provision for the setting up of Courts of Inquiry in cases where the Minister of Labour, with or without prompting by either of the parties, considers that the facts of a dispute should be investigated publicly and impartially. It may be noted that Sir George Askwith in 1912 reported in favour of such a provision after a special mission to examine the labour laws of Canada. A Court of Inquiry is appointed *ad hoc*, and, unlike the Industrial Court, has the power of compelling the attendance of witnesses and the disclosure of information. It reports to the Minister of Labour the information obtained and the conclusions arrived at. The report is laid before both Houses of Parliament. During the short period the Act has been in existence there have been five enquiries, the last being in May, 1922.

Recourse to arbitrators appointed for a specific case is not infrequent; but the great majority of cases come to the Industrial Court, and it is to that Court we must look to see arbitration in its characteristic form in this country.

It will not, therefore, be out of place to look at the constitution of this Court in some detail. The Court consists of persons appointed by the Minister of Labour, of whom some shall be independent persons, some shall be persons representing employers, some shall be persons representing workmen, and, in addition, one or more women. The Act thus takes care that all points of view are represented on the Court: the independent point of view, the employers' point of view, and the workmen's point of view. Further, the Court may have the assistance of assessors. The Minister of Labour appoints the President and Chairmen from the independent persons. The Act expressly imposes certain requirements on some of its members. The President and Chairmen are required to be independent. The "representing" members are required to represent their respective interests. The requirement imposed on them is a wide one; they are to "represent": that is, to see that the point of view of the party whose interests they represent is duly presented to, and considered by, the Court in any case on which they may sit. The requirement imposed on the President and Chairman and the "representing" members is a continuing one. Any one who fails to carry out the requirement imposed on him fails in his duty. Woman, as usual, comes out on top; no qualification is required of her. But the body of which the various persons above enumerated are members is a Court, and a Court implies that the questions under consideration are to be heard and determined judicially. Whatever interests (if any) any particular member may represent must give way to the judicial determination of the Court. This, however, does not exhaust the matter. To be an effective member, each individual member must be familiar with industrial conditions, and be acquainted with industrial and workshop life. To use the phrase of Bacon, he must be a "full man"; he must have full knowledge. Unless the President or Chairman has such knowledge, no reliance could be placed on his independence; and unless the other members who "represent" their respective interests have such knowledge, they may, when called upon, fail to discharge their duty. In fact, the Statute, as well as commonsense, requires that all the members must make themselves individually acquainted with each trade or industry, its customs, practices, technicalities, its agreements, national and local, and such like matters. Much is required of the members, because much is expected of the Court.

Since the Court was established at the end of 1919, four volumes of decisions have been published. The decisions have been given in cases of the most diverse character. Many, and perhaps most, of the cases have been straightforward claims for alterations in, and adjustments of, rates of wages, but other questions relating to working conditions, customs and practices of the workshop and of the trade, and the construction of industrial agreements have also been decided by the Court. Without wearying you with illustrations, I may say generally, that the cases actually dealt with by the Court show that there is probably no question likely to arise between employer

and workman or between workmen and workmen which cannot be put in form and appropriately submitted for arbitration if the parties so desire.

The cases that come before the Court may be differences between individual firms and their workmen or differences between workmen and workmen in an industry. The decisions have sometimes a large circulation running into many thousands.

In what way does the Court discharge its duties and, judged by its decisions, does it represent any new tendency or developments? I am always chary about citing what is being done abroad in support of what ought to be done at home, for, as a rule, experience abroad has no very direct effect upon developments here. I should like, however, for the purpose of my present point, to make allusion to the arbitration tribunals in the Australian Commonwealth. Those tribunals form part of the judicial system of Australia and their procedure is assimilated to that of the courts of law. Cases are tried and argued like civil actions, and the decision of the Court is contained in a reasoned judgment. This is in striking contrast to the practice of industrial arbitrators in this country, whose methods were somewhat casual and whose awards studiously avoided a statement of the grounds on which the decision had been reached.

The Industrial Court has pursued a *via media* between these two extremes. In it, we see something akin to the beginnings of the old Courts of Common Law which sat in Westminster Hall. The early decisions of those Courts are decisions on particular facts rather than on principles of law, for the principles of law had hardly yet been ascertained. Customs, local and national, are recognised and by-and-bye rules are propounded and gradually there emerge settled principles which to-day appear commonplace, so ingrained have they become in our social every-day life. What we regard as the common law of the land has thus been of slow and gradual growth; but it had a beginning, and under whatever verbal guise it may have appeared, the authority for early decisions must have been nothing more than some concept or principle springing from the general social conscience.

It is a recognition of this fact which has led the Industrial Court to move considerably in advance of previous arbitration practice in this country. Its decisions are in the main reasoned decisions, not elaborate, but sufficiently explicit to show by what considerations the Court has been moved. In short it has made a beginning in the task of laying down a *corpus* of industrial common-law. Whether such a task is by the nature of the case impossible or impracticable is a subject more fit for discussion by you than for dogmatism by me.

The superiority of a permanent tribunal dealing daily with disputes covering an immense variety of trades, over a single arbitrator casually called in on occasion and interrupting his ordinary pursuits in order to deal with questions of a technical character in an atmosphere to which he has not had the opportunity of becoming acclimatised, hardly needs argument. The Industrial Court is on a different footing from the Committee on Production and the Interim Court of Arbitration. The latter tribunals wielded certain compulsory powers, and if the parties wished compulsion to attach to an award, they could have recourse under the Munitions of War Acts and Wages (Temporary) Regulation Acts to these tribunals. The Industrial Court, on the other hand, rests upon an entirely voluntary basis, both as regards appeals to it and as regards the observance of its decisions. Almost unique, therefore, among State institutions, it can continue and function only so long as it gives satisfaction. It is always possible for persons desiring arbitration to choose some other form of tribunal.

A court of equitable jurisdiction must more or less keep in line with the silent movements of society; and nothing would be more fatal to its existence than that the Industrial Court should blindly follow even its own precedents and declarations. But it is one thing for the Court to be sensible of deep seated changes in industrial ethics, and another that it should become the sport of every gust of popular feeling, or an unreasoning worshipper of the latest craze in social theory. An arbitration tribunal that aimed at nothing more than immediate popularity, might win approval to-day, but would become, as it would deserve to become, a thing of contempt to-morrow. Those who would administer justice must place their feet on firm ground. A body of rules and principles is a safeguard against sudden and capricious change and a protection for the Court itself against automatic movement along the line of

personal feeling and bias. Its value lies, therefore, not only in ensuring decisions which are shaped solely by considerations of justice, but also in lessening what may be called the hazards of arbitration. We have seen that much of the shyness of employers and workers towards arbitration in the past has been due to the fact that the risks attending an appeal to it have been unduly great. Too much may be thought to depend upon the mere personality of the arbitrator. Towards a Court keeping within the boundaries of known and proclaimed principles, the attitude of parties may become one of greater assurance. Roughly, the margin of possible error in a decision of the Court upon any proposed case would become known, and a case could be brought with confidence that the decision would be as free from personal prejudice as human pronouncements can be.

It would thus appear that we are at the beginning of a new era in the settlement of industrial differences. Progress may not be rapid; but the Industrial Court has appreciated the philosophy of its task. By moving forward on methodical lines, not seeking notoriety, it brings some assurance that the foundations are being laid for a serviceable and satisfying structure.

DISCUSSION.

Mr. J. W. Pearson, in opening the discussion, said he would like to add one word of appreciation not only of the Industrial Courts, but of the Joint Industrial Councils. He had had some little experience of troubles and difficulties with workpeople, and he had gone through the evils of a strike which had pervaded an entire industry, and which, in common, he thought, with many other employers in similar cases, might have been avoided by a little amount of common sense and give-and-take on both sides, which was, perhaps after all, what enabled Industrial Courts and Councils to be constituted.

The author had rightly said that the institution of the Joint Industrial Councils was very largely dependent upon a fairly complete organisation of both sides of industry—the employers and the employees. In many industries the employers were very well organised, but he thought there were comparatively few in which the employers were anything like so well organised as the employees. He thought that was the cause of very many of our industrial difficulties to-day. He had noticed that, even amongst those industries which were fairly well organised, there were very few employers who were as capable of presenting a reasonably argued case as were the employees. That was one of the factors which was largely overcome by Joint Industrial Councils. But as against that he had found one important difficulty. Perhaps he had not sufficiently appreciated the value of the Industrial Court, but, speaking of the Joint Industrial Councils, he had found there was a great difficulty in enforcing their awards. He recognised that an Industrial Council depended for its continued existence very largely upon the justice of its decisions, and perhaps the greatest safeguard was that any decision arrived at by a Joint Industrial Council—anything which was passed in the shape of a definite resolution—must be passed by a majority on both sides of the table, the employers and the employees; and he thought it was a little curious, but, nevertheless, satisfactory, to recognise that, where a violent difference of opinion did exist, it was usually because one side or other of the table had taken an extravagant view of its own position, which was modified by open debate with the other side. He had never found a resolution proposed of a nature that could not properly be accepted by both sides, and in connexion with which there had been any attempt to force the measure on the trade. There was one other difficulty, namely, that the organisation of the work people depended largely on their membership of Trade Unions. It was difficult to see any alternative than that the employees' side should be representatives of Trade Unions. Yet that rather tended in the direction of forcing employers to do something which so many of them had tried to avoid, namely, imposing upon their employees the necessity of being members of one or other Trade Union. He was not going to say anything as to the wisdom of that step, because he knew many shops were Union shops and others, on the other hand, were non-Union shops, but it was a factor which employers had all noted, that so long as there appeared to be some possible element of strife—he said it with a certain measure of regret—and some opportunity of suggesting an increase in rate of wages, that was the factor which made men most prone to join Trade Unions and to pay their weekly contribution. In times like the present, when the country was being faced with actually reducing wages and tightening conditions, the men themselves did not see the advantage of being members of a Trade Union organisation, and to-day the membership of most of the leading Trade Unions was enormously reduced from what it had been in the days when successive disputes had resulted always in an advance in the rate of wages. It therefore followed that as the Joint Industrial Councils on the employees' side consisted of Trade Union representatives, if their membership fell too low, they were not sufficiently representative of the

men whom they purported to represent, and the difficulty was how to bring those several factors into line so as to ensure a proper discussion on both sides of the points which were principally concerned, and to ensure their observance subsequently. So surely as men dropped their Unions, so surely was there an increase in the non-Union shops, and so surely there followed a considerable number of cases where decisions which were obviously for the general benefit of the trade could not be imposed for that reason upon those employing firms who did not put them into effect. He hoped the time would come when it would be found that Joint Industrial Councils operated so largely for the benefit, not only of individuals, but of national trade, that some means might be provided of ensuring that, so long as they were representative of a majority of those interested, there should be some means of compelling the adherence of those who had abstained from being parties to the representation.

Mr. John Baker (Iron and Steel Trades Federation) remarked that the author had hardly been quite fair to the Boards of Arbitration and Conciliation. Such Boards did not meet in a heated atmosphere. They met to take the dispute away from a heated atmosphere. A man in a works had a grievance. He went to his foreman and got no redress. He got his works' delegate or shop steward to go to the foreman's superior, and then he got no redress. He went to a Board delegate and had the matter referred to the Board, or brought in his Trade Union Officer, who had a discussion with the General Manager. Failing settlement, the point went to the Conciliation Board, where there was not a dissatisfied workman and a disgruntled foreman, but a group of people who knew neither of the parties concerned, and who were there merely to consider the facts of the case. Those people knew the conditions of the trade in other works, and the traditions and customs of the trade, and there was no heated atmosphere. Such a Board had statutory meetings; they were not mere war Councils, but were there to discuss all sorts of matters. For instance, he had been Secretary of one of those Boards, and had taken some part in establishing it for the coke trade in Cumberland. If an employer dismissed a workman, and he (Mr. Baker) did not like it, he could have a meeting of the Board to discuss the employer's right to dismiss the workman. If a workman left and the employer appointed another workman, not the one who he (Mr. Baker) considered ought to have the job he could call a meeting of the Board and discuss whether the employer had the right to put that particular man on to that particular job. If there had been any fighting about it, it would have been at that particular coke yard and not at the Board meeting. At the Board meeting one had to argue the matter out with other people who knew as much about the case as one did oneself. He believed that the Whitley Councils and the Industrial Councils were a big step ahead of those Boards of Conciliation, because, after all, the Boards were largely taken up with questions of wages and conditions of employment. The Whitley Councils went a few steps further than that, and considered the comfort of the workmen. With regard to the change which had taken place—and he thought for the better—in the old days one went to arbitration in which the arbitrator was generally a lawyer or somebody with a legal training. That arbitrator sat with a blank mind. He knew nothing about the quarrel or dispute or the industrial conditions. He had attended determined not to know. Neither the workman nor his representative had appreciated that mental attitude. They had thought it was unnecessary to prove the obvious, but the lawyer made them prove it; he could only see the things that were laid before the Court, and he could only see the things that were laid before the Court in a particular form and when some sort of proof was given that the statements made were true, and then made his decision on that. But when one went to the Industrial Court, or to the Committee on Production, one went before men who were really trying to find out something about industry, and instead of sitting there just absorbing the information which both sides were pelting at them, they would interpolate every now and again questions which cut right across the argument and let one see that they clearly understood what both parties were arguing about, but that they desired a little information to help them to make up their minds as to the justice of the case being put forward. It was a refreshing experience to attend both the Committee on Production and the Industrial Courts. He thought that was a step in the right direction. If a Court was going to take the attitude that it neither knew nor cared about the dispute, it was not going to help the workman or the employer. The Industrial Courts had definitely taken a different attitude from that. They were trying to establish industrial peace on fair lines, and that was a tendency which everybody ought to encourage. The paper was a valuable addition to the literature on the subject, and ought to help some of those concerned to come to wiser conclusions in the future.

The Chairman said he quite agreed with the last speaker that the author's paper was a very valuable addition to the literature on the subject. It required some study, because its complexities had not been easy to follow as it had been delivered. The historical part of the paper was not the least valuable. It enabled one to see the various attempts which had been made during the course of many years to arrive at some system that might be of service. In

the light of present-day experience some of those attempts seemed to be almost quaint, but, still, it would be recognised, when the paper was read, that as early as the year 1800 one of the best constituted trades in this country for the settlement of its differences—the cotton trade—had taken the lead in trying to find a system by which settlements could be arrived at; and one of the gentlemen who, in later days, had taken a great part in dealing with settlements in the cotton trade, Sir David Shackleton, was present in the room that evening. There was one thing during the 19th century which seemed to have obsessed the minds of those who were dealing with industrial disputes. It was probably the outcome of the feeling of the country as a whole. They could not get away from the idea that any infraction of an award, or any attempt to break away from a decision which was capable of being interpreted in two ways, must mean that the full penalties of the law had to be brought in. A Union or an Association of employers might impose their own penalties, but when one came to the general law of the land coming in to enforce an arbitration, then one got compulsory arbitration which was the feature of all those attempts. It would be futile nowadays to consider what might have been the effect upon this country if, in 1867, Lord St. Leonards's very earnest attempts to arrive at some system had not been stopped in the House of Lords, where ten members attended and nine voted against a particular clause in the Bill. He did not think really, if they had had a different opinion, and if the House of Commons had had a different opinion, that the law would have lasted, or been of any more effect than some of the dead letter laws previous to it. At that time there was a great change going on in industry, and compulsion could have been no more brought against the great masses of employees, many of them doing in vast numbers the same kind of work, than it could at the present day. He remembered an incident during a threatened coal strike, when the then President of the Board of Trade, Mr. Churchill, intimated, as the coal miners were leaving the room, that unless arbitration was agreed to it would be necessary to have an Act of Parliament through both Houses within 24 hours, making arbitration compulsory by law. An old friend of his (the Chairman's) now deceased, Mr. William Abrahams, turned to Mr. Churchill and said, "Mr. Churchill, you cannot put 600,000 men into prison." The answer was obvious. Mr. Abrahams was correct. The reason why there could not be compulsory arbitration, and why it would not be successful in this country, was because there had grown up, by the very growth of industry, a regular system of collective bargaining. One heard a good deal said against collective bargaining, and at the present day it was occasionally said that each employer should make an individual bargain with each man. The system of industry prevented that. There had to be rates of wages. In certain industries there had to be minimum wages, and the individuals who were employees would be guided by that general rule. Therefore, there were various classes of individuals who must be governed by a general agreement or a general award. Perhaps that had reached its highest fulfilment towards the last two years of the War. The difficulty of getting equal allowances to different classes of men in different trades at a time when the cost of living was rising very rapidly and when wages could not keep pace with it, had been extremely difficult. The Courts of Arbitration had been overwhelmed with applications for immediate decisions. The number of arbitrators capable of doing the work was limited. The importance of co-ordination between their decisions had been extremely great. Interference from outside had been also a very dangerous thing. When, in the midst of careful arbitrations, there came such a bombshell as the 12½ per cent. suddenly thrown into the wage system of this country, what were the arbitrators to do? The result of that had been that, with the consent of the Unions concerned and of the employers, an agreement had been made whereby 53 Trade Unions together with the employers in the various branches of the engineering industry, engaged to abide by single awards of the Committee on Production. That was collective bargaining perhaps in the highest form known in this country, and might possibly to a certain extent be a thing which might in times of crises occur again; but with the re-action after the war it had come to an end. It had been intended really only to last as a war measure but the re-action after the War perhaps tended to make it come to an end at a more early date than might otherwise have been the case. One of those Unions had broken away—the iron moulders. They considered that their place in industry should be better relatively to the other Unions than the other Unions had either been willing to concede or than the employers chose to recognise. They broke away and struck and injured the engineering industry very seriously indeed by that very prolonged strike beginning in 1919. Whatever might be said about compulsory arbitration in the War, or whatever might be said about some of the decisions at different times which had been given, the outcome of those acts and of that work had been that a permanent Court of Arbitration, available but not compulsory, of which Sir William Mackenzie was head, had been established by the Act of 1919. and he was certain that that was a protection in some sense to this country. If we had a big war again, or a crisis in this country in which the imports of food, for instance, were for any reason in danger, and when the cost of living

INDIAN SECTION.

Friday afternoons.

JUNE 1, at 4.30 p.m.—AUSTIN KENDALL, I.C.S., rtd., "The Participation of India and Burma in the British Empire Exhibition, 1924." SIR CHARLES C. MCLEOD, Member, Board of the British Empire Exhibition, will preside.

JUNE 15, at 4,30 p.m.—SIR JOHN H. MARSHALL, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture.)

HOWARD LECTURES.

Monday evenings at 8 o'clock.

STANLEY S. COOK, B.A., M.I.N.A., M.I.M. (Parsons Marine Steam Turbine Co.), "The Development of the Steam Turbine." Three Lectures. April 30, May 7, 14.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, MAY 14 .. University of London, University College, Gower Street, W.C., 5 p.m. Prof. G. D. Hicks, "Kant's Theory of Beauty and Sublimity." (Lecture I.)
5.30 p.m. Prof. A. Feuillerat, "Studies in Shakespearean Technique." (Lecture I.)
At King's College, Strand, W.C., 5.30 p.m. Prof. R. Dyboski, "Outlines of Polish History." (Lecture III.)
At King's College for Women, 61, Campden Hill Road, W., 4.30 p.m. Prof. V. H. Mottram, "Nutrition." (Lecture IV.)
Victoria Institute, Central Buildings, Westminster, S.W., 4.30 p.m. Prof. T. G. Pinches, "Assyro-Babylonian Israel Likenesses and Contrasts."
Architectural Association, 34, Bedford Square, W.C., 8 p.m. Mr. C. Brummer, "Danish Architecture."
Geographical Society, Kensington Gore, S.W., 5 p.m. Prof. J. W. Gregory, "The Banda Arc: Its Structure and Geographical Relations."
Faraday Society, at the Chemical Society, Burlington House, Piccadilly, W., 8 p.m. 1. Messrs. E. P. Perman and H. L. Saunders, "The Vapour Pressures of Concentrated Cane Sugar Solutions." 2. Mr. E. W. J. Mardles, "The Elasticity of Organogels of Cellulose Acetate." 3. Mr. D. Stockdale, "An Example of Polymorphism in an Intermetallic Compound." 4. Mr. A. L. Norbury, "Some Experiments on the Hardness of Spontaneous Annealing of Lead." 5. Messrs. F. C. Thompson and E. Whitehead, "Some Notes on the Etching Properties of Alpha and Gamma Forms of Tricarbide of Iron."
Brewing, Institute of, 30, Coventry Street, W. 7.30 p.m. (Joint meeting with Biochemical Society.) 1. Dr. A. Slator, "Biochemical Aspects of Fermentation." 2. Prof. V. H. Blackman, "Physiological Aspects of Germination." 3. Messrs. J. L. Baker and H. F. E. Hulton, "Chemical Aspects of Germination."

TUESDAY MAY 15 .. Statistical Society at THE ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.15 p.m. Mr. D. R. Wilson, "Some Recent Contributions to the Study of Industrial Fatigue."
University of London, University College, Gower Street, W.C., 5.30 p.m. Prof. A. Feuillerat, "Studies in Shakespearean Technique." (Lecture II.)
King's College, Strand, W.C., 5.30 p.m. Dr. H. W. Carr, "Blaise Pascal: Tercentenary of his birth, June 19th, 1923." (Lecture I.)
Royal Institution, Albemarle Street, W., 3 p.m. Prof. A. C. Seward, "Arctic Vegetation of Past Ages."
Transport Institute of, at the Institution of Electrical Engineers, Savoy Street, Strand, W.C., 5.30 p.m. Mr. G. J. Shave, "The Design and Maintenance of Commercial Motor Vehicles."
Anthropological Institute, 50, Great Russell Street, W.C., 8.15 p.m. Mr. J. H. P. Murray, "Native Administration in Papua."
Sociological Society, 65, Belgrave Road, S.W., 8.15 p.m. Dr. G. Slater, "The Psychological Basis of Economic Theory."

WEDNESDAY, MAY 16 .. University of London, University College, Gower Street, W.C., 3 p.m. Prof. E. G. Gardner, "The Composition of the Divina Commedia." (Lecture II.)
5.30 p.m. Prof. P. Geyl, "Dutch Architecture in the XVIth and XVIIth Centuries." (Lecture III.)
5.30 p.m. Mr. R. F. Green, "The Practice of Extra Illustration of Books."
5.30 p.m. Prof. A. Feuillerat, "Studies in Shakespearean Technique." (Lecture III.)
Geological Society, Burlington House, Piccadilly, W., 5.30 p.m.
Meteorological Society, 49, Cromwell Road, S.W., 5.0 p.m. 1. M. de Carle S. Salter and Mr. J. Glasspoole, "The Fluctuations of Annual Rainfall in the British Isles considered cartographically." 2. Mr. A. W. Clayden, (a) "An improved Actinograph." (b) "Note on the Influence of a Glass Shade." 3. Capt. E. E. Benest, "Notes on the 'Sumatras' of the Malacca Straits."
Microscopical Society, 20 Hanover Square, W., 7 p.m. (1). Mr. L. Taverner, "The Principles and Application of Technical Metallurgical Microscopy." (2). Mr. W. M. Ames, "Applications of the Microscope in the Manufacture of Rubber."
Constructive Birth Control Society, Essex Hall, Essex Street, Strand, W.C., 8 p.m. Earl Russell, "Progress and the Law."

THURSDAY, MAY 17 .. University of London, University College, Gower Street, W.C., 5.30 p.m. Dr. H. A. Lorentz, "The Rotation of the Earth and its Influence on Optical Phenomena."
5.30 p.m. Mr. C. Pellizzi, "Bernardino Telesio E La Filosofia Europea." (In Italian.)
2.30 p.m. Prof. W. M. Flinders Petrie, "Recent Discoveries in Egypt."
5.15 p.m. Prof. J. E. G. Montmorency, "Customary French Law." (Lecture IV.)
At King's College, Strand, W.C., 5.30 p.m. Principal L. P. Jacks, "The Higher Education and the Community of Nations."
5.30 p.m. Dr. O. Vocadlo, "Czechoslovakia" (Lecture II.)
Royal Society, Burlington House, Piccadilly, W., 4.30 p.m.
Chemical Society, Burlington House, Piccadilly W., 8 p.m.
Mining and Metallurgy, at the Geological Society, Burlington House, Piccadilly, W., 5.30 p.m.
Royal Institution, Albemarle Street, W., 3 p.m. Prof. E. G. Coker, "Pressure and Stresses."
Central Asian Society, at the Royal United Service Institution, Whitehall, S.W., 5 p.m.

FRIDAY, MAY 18 .. University of London, University College, Gower Street, W.C., 5 p.m. Mr. W. Macnab, "Some Scientific Principles of Chemical Industry." (Lecture III.)
At King's College, Strand, W.C., 5.30 p.m. (Shakespeare Association). Mr. J. D. Wilson "Folio and Quarto Texts."
Royal Institution, Albemarle Street, W., 9 p.m. Mr. W. M. Mordey, "Recent Studies on Alternating Magnetism."

SATURDAY, MAY 19 .. Royal Institution, Albemarle Street, W., 3 p.m. Mr. J. B. McEwen, "Harmonic Evolution."

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2

NOTICES.

TWENTIETH ORDINARY MEETING.

WEDNESDAY, MAY 9th, 1923; MR. D. MILNE WATSON, M.A., LL.B., Governor of the Gas Light and Coke Company, in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Banerjee, Satya Kishore, M.A., B.L., Calcutta.
Cannings, Reginald Edward, Bath.
Herbert, Charles Edward, London.
Jepson, Willis Linn, Ph.D., California, U.S.A.
Keiller, Fred G., London.
Kinloch, John, Mergui, Burma.
Larrouy, Francis Isidore, Demerara, British Guiana.
Zollikofer, R. V., Rangoon, Burma.

The following candidates were duly elected Fellows of the Society:—

Cadman, Sir John, K.C.M.G., D.Sc., Pres.Inst. M.E., London.
Hanson, Joseph, J.P., Rochdale.
Parsons, Joseph Greeley, M.D., S. Dakota, U.S.A.
Saran, Sahu Brijpal, B.A., United Provinces, India.

A paper on "Surface Combustion, with Special reference to recent Developments in Radiophragm Heating" was read by PROFESSOR WILLIAM ARTHUR BONE, D.Sc., Ph.D., F.R.S.

The paper and discussion will be published in a subsequent number of the *Journal*.

HOWARD LECTURE.

On Monday evening, May 14th, MR STANLEY S. COOK, B.A., M.I.N.A., M.I.M. (Parsons Marine Turbine Co.), delivered the third and final lecture of his course on "The Development of the Steam Turbine."

On the motion of the Chairman, SIR DUGALD CLERK, K.B.E., F.R.S., a vote of thanks was accorded to MR. COOK for his interesting course.

The lectures will be published in the *Journal* during the Summer Recess.

PROCEEDINGS OF THE SOCIETY.

DOMINIONS AND COLONIES AND INDIAN SECTIONS.

(Joint Meeting).

FRIDAY, MARCH 16TH, 1923.

EARL WINTERTON, M.P., Under Secretary of State for India, in the chair.

THE CHAIRMAN, after remarking that he felt it a great honour to preside over a gathering which included their Excellencies the Japanese Norwegian and Colombian Ministers, the Chinese Chargé d'Affaires, Surgeon W. W. King (representing the United States Public Health Service) and many other distinguished visitors, said the lecturer, Lieut.-Colonel Sir Leonard Rogers, was well known to all those present. He entered the Indian Medical Service in 1893, and served in it with great distinction for many years. He was the author of various scientific papers in medical journals, and had filled many high positions in India, including that of Professor of Pathology at the Medical College of Calcutta. He was now a member of the India Office Medical Board. India was greatly interested in the leprosy problem; the census returns showed that there were something like 110,000 lepers in India to-day, and he feared the actual number was greatly in excess of that figure, large though it was. For many years past the authorities had been fully alive to the necessity for taking all possible remedial measures. In 1920, moreover, an amended Leper Act was passed by the Legislative Council which gave the Local Governments greater powers of supervision and control, enabled them to establish leper asylums and provided further regulations for restricting the movement of lepers. Owing to the fact that, under the new Constitution, health was a provincial subject, dealt with by Ministers responsible to the local legislative bodies, the Act was permissive only, and not compulsory; and, he regretted to say, had not yet been adopted in all the provinces. It was in force throughout Bengal, and in certain areas in Bombay and Burma; while other Provinces were, he believed, considering the desirability of adopting it. No doubt if it achieved its objects where it had been applied, it would be extended. In addition

to measures of that kind, during the last few years a great advance had been made in the medical treatment of the disease, which would be dealt with in the paper. There were few diseases in the suppression of which the recent great advances in scientific knowledge had been more helpful than in the case of leprosy. As one who had travelled widely, particularly in different parts of the British Empire in Asia and Africa, he was confident that the opening up of undeveloped territory in a large part of the Empire depended on the ability of scientists to discover the cause and cure of the diseases which affected it. That might not be true of leprosy, which only affected the European population to a limited extent, but it was true of other diseases. There were parts of Africa which could not be developed at the present time owing to the prevalence of blackwater fever and sleeping sickness, and, therefore, quite apart from the moral and humanitarian aspects of the matter, anything which could be done to reduce or suppress such diseases was of the very greatest commercial value to the whole British Empire.

The paper read was :—

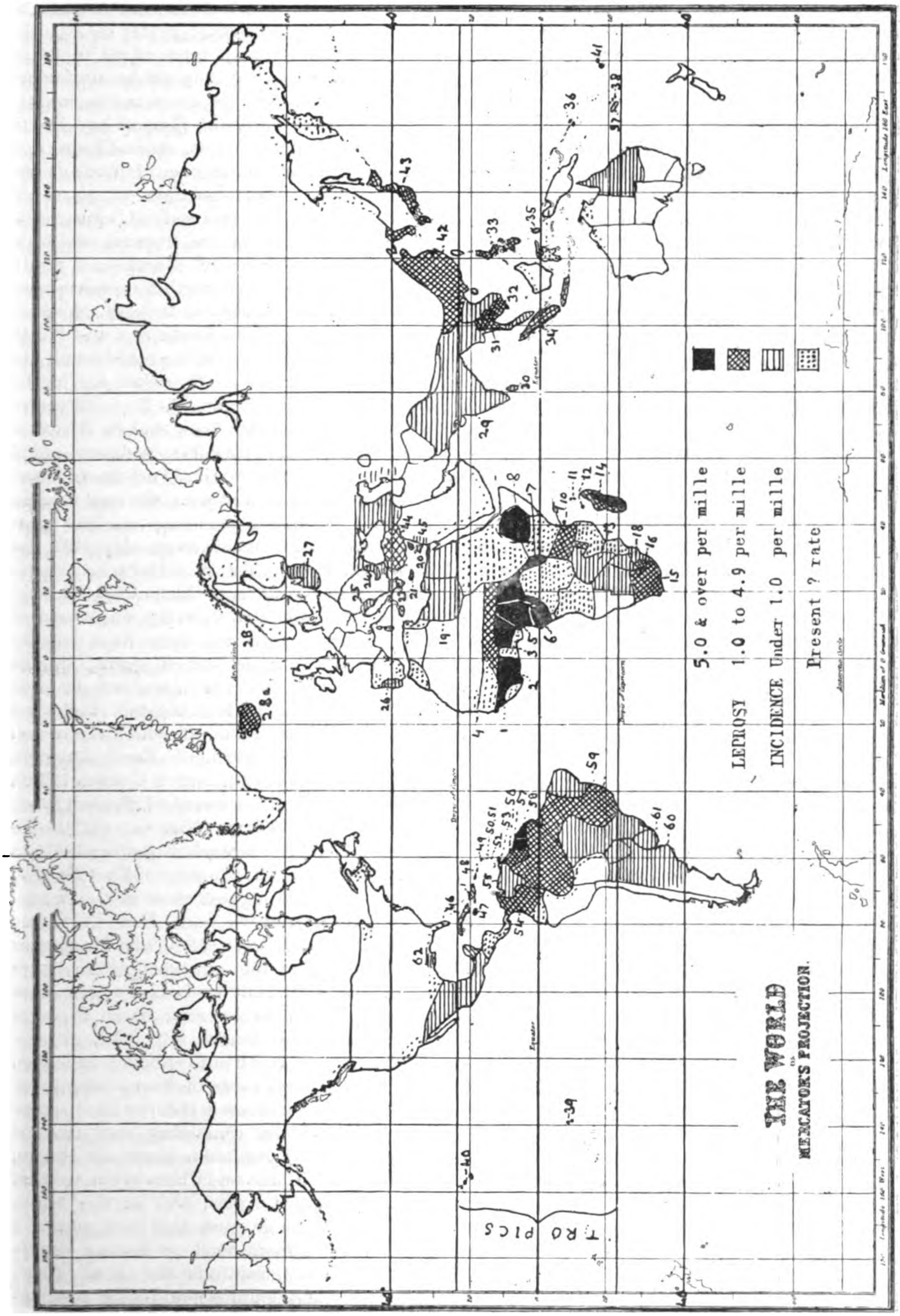
RECENT ADVANCES TOWARDS THE SOLUTION OF THE LEPROSY PROBLEM.

By Lieut.-Col. Sir Leonard Rogers, C.I.E., M.D., F.R.S., I.M.S., Ret.

The leprosy problem is as old as our records of civilisation, for the disease was known in Egypt among negro slaves from the Soudan in 1350 B.C., and is mentioned about the same time in Vedas in India, as well as in Biblical records, although in those ancient days, as well as much later, it was doubtless confused with leucoderma and psoriasis, for the description of a leper as "white as snow" is not applicable to any form of *elephantiasis Græcorum*, or leprosy, of present day nomenclature; and such confusion goes far towards explaining the exaggerated belief in the great infectiousness of the disease of the Middle Ages, which still remains to some extent, as witnessed by the appearance of a leper in an American court of justice leading to the flight of those present, including the "judicial ermine," and the very recent absurd objection of an English village to the presence of a single leper in a well-equipped nursing home with ample grounds around it. To enable the present position of the problem to be grasped it will be advisable to trace briefly the spread of leprosy over the globe, and describe its present distribution.

Spread of Leprosy over the World.

The first known appearance of leprosy in Egypt among negroes from the Soudan is of great interest, in view of the fact that Tropical Central Africa still shows the most extensive areas of high leprosy incidence in the world, from whence the disease was carried nearly three thousand years later to the Western Hemisphere by means of the slave trade, so that Africa was probably the original seat of the disease, from whence it spread over Asia in prehistoric times, China being apparently free in 1500 B.C., although certainly infected in 100-200 B.C. The history of the subsequent spread over Europe and America is known, for leprosy was probably introduced into Greece by the armies of Darius, and became common there about 200 B.C., was carried to Italy by the return of Pompey's soldiers from the East in 62 B.C., and was described by Galen in Germany in 180 A.D. Spain was infected by Roman troops in the fifth and sixth centuries, while by the eighth and ninth centuries France and much of Great Britain had sufficient cases to lead to laws against the disease being introduced, and by 1229 there were said to be 2,000 leper houses in France alone, as well as a large number in Great Britain, the disease having increased after the Crusades, although present long before those events. During the fourteenth and fifteenth centuries a great decline of leprosy in Western Europe became established, which was particularly marked in England, being apparently hastened by the Black Death of 1349, which is supposed to have destroyed "not much less than one half of the population," the outcast lepers always suffering most during such calamities as epidemic diseases and famines to the present day, as shown by the effects of famines in parts of India in the last decade of the nineteenth century in decreasing leprosy in India. About the time the disease was decreasing in Europe the discovery and colonisation of the Western Hemisphere infected that region, where all the evidence points to the indigenous Indian population having been previously free from the disease, those isolated in the dense Brazilian forests still remaining so, the Portuguese and Spanish conquerors first introducing the disease, Portugal and Spain still showing a considerable amount of endemic leprosy, while the affection was spread greatly by the millions of negro slaves imported from the very areas of


5.0 & over per mille
LEPROSY 1.0 to 4.9 per mille
INCIDENCE Under 1.0 per mille
Present ? rate
THE WORLD
ON
MERCATOR'S PROJECTION.
TROPICS

Tropical Africa which still are most infected, and later by immigrants from China and India. Lastly, in the latter half of the nineteenth century, very rapidly spreading outbreaks of leprosy have occurred in the Sandwich Islands, New Caledonia, Loyalty and Marquesas Isles of Oceania, that of New Caledonia certainly and of Hawaii probably having been due to infection by Chinese immigrants. The whole history of the spread of leprosy is essentially that of a slowly communicable disease, the recent rapid spread in some of the Oceania islands within a single decade being alone sufficient to exclude the hereditary theory of origin of the disease, which was so generally accepted, to the exclusion of the infective theory, as late as the report of the Committee of the Royal College of Physicians of London of 1865, while heredity also fails to account for the frequent infections of Europeans with no hereditary taint who have come into close contact with lepers in the tropics, most frequently through intimacy with the native women, as recorded in Hawaii, British Guiana and elsewhere; but with the discovery of the Lepra bacillus by Hansen of Norway in 1874 the hereditary view rapidly lost ground, and is now only of historical interest, like Hutchinson's prebacteriological fish-eating theory of the origin of leprosy.

THE WORLD INCIDENCE OF LEPROSY AND ITS RELATIONSHIP TO METEOROLOGICAL CONDITIONS.

Maps hitherto published only show the occurrence of leprosy in various countries of the world without giving the rates per mille of population, and consequently furnish very little idea as to where the cases are sufficiently numerous to constitute the disease a serious problem, but in the course of a study of the literature of the subject for several decades back, which has occupied me, in my spare time, for eighteen months, I have noted all available figures and worked out the map, of which I show you a lantern slide, shaded to bring out the rates per mille, which furnish much more definite ideas regarding the greatness of the problem of the control of this preventable disease, while I have also studied the rainfalls of the infected countries and embodied the results in a second map of its world distribution, which bring out an important relationship of which I only have time to give a brief description.

In the rainfall map rates of 60 to 90 or more inches annually, shown by uniformly dark shading, are seen to occur mainly in the tropical regions of Central and South America, Central Africa, Indo-China and the East Indian and Oceanic Islands, while the moderately high rainfalls of 30 to 60 inches, shown by crossed oblique lines, also chiefly occur in the tropical and sub-tropical zones up to 40° North and South latitudes, while in the north temperate zone such rates are also seen in Iceland, Norway, Central Europe, Kamchatka and the North of Japan and Korea. On the other hand, the extremely low rates of 10 inches and under occur within the tropics in Peru, Western Bolivia and Northern Chile and in Africa in the Southern part of the Sahara desert and in South West Africa in Portuguese and formerly German territory. On now turning to the leprosy incidence map we find that these last mentioned very dry tropical areas are the only important countries within the tropical zone which escape leprosy; while, on the contrary, every single one of the countries with the very high leprosy rates of 5 per mille and upwards, shaded uniformly dark on the map, are situated in tropical areas with high rainfalls, including the following, after each of which the actual rate per mille is given. In South America, French Guiana (11.0), Dutch Guiana (25.0), in Africa, French Guinea (5.0), French Ivory Coast (60.7), North Nigeria (5.2), the Kameruns (20.0), French Equatorial Africa (13.0), and in a 150 mile strip of East Belgian Congo (200) the highest rate in the world, while in Oceania we have New Caledonia (26.0), Loyalty Islands (35.0), and Marquesas Islands (66.7), all extremely high rates when we recall that in India, where cases of leprosy are to be seen daily in large towns, the rate is now only 0.32, or one-fifteenth to one 200th of the above incidences. The next highest rates of 1 to under 5 per mille, shown by crossed oblique lines, occur in nearly all the remaining wet tropical areas of South America, parts of Africa, much of Indo-China and China in the tropical and sub-tropical zones, and in the North temperate zone in just the very places I have already mentioned as having exceptionally heavy rainfalls for that zone; thus showing a definite world-wide relationship between heavy rainfall and high leprosy incidence, which is most marked

in the hot moist areas within 80° F. isotherm shown in the rainfall map.

The general relationship between high leprosy incidence in wet, and low ones in dry areas was noted by the Indian Leprosy Commission report of 1893, and recently I have made maps showing the rates per mille in India and the rainfalls for the same areas, worked out from the records of over two thousand stations, a lantern slide of which I now show you, from which it appears that the very low rates of from 0.06 to 0.15 occur in every area with less than 30 inches annually, including the North-West Frontier, Punjab, Rajputana, Sind and the dry central inland parts of Madras and Mysore, while rates of over 0.5 per mille nearly all occur in areas with from 50 to 150 inches, namely Burma, Assam, Orissa, the Western Chattisgarh Division and Bastar and neighbouring states of the Central Provinces, and the very wet Bombay and Malabar Coast, the latter area of high leprosy incidence, however, extending into the comparatively dry area of the Deccan and Berar, which long had close commercial intercourse with Surat and Bombay and forms the only important exception to the rule of high rainfall wherever there is high leprosy incidence in the Indian Empire. The contrast between the high rates of the wet Western Himalaya hill districts of Kamaon and the Punjab with the very low rates of the dry subjacent plains is especially noteworthy, while the data of the leprosy incidence, rainfall and average humidity all decrease regularly as we ascend the Gangetic Valley above the deltaic area from Behar to Meerut, showing that the humidity is the essential factor, which is confirmed by the great contrast between the high 4 p.m. humidities of the Western Himalayan hill stations and the low readings of the subjacent plains. The explanation I have suggested of the exceptionally high leprosy rates in hot humid countries is that the innumerable insect bites there experienced afford sites of entry through the skin for the lepra bacilli derived from neighbouring lepers.

The Communicability of Leprosy.

There is no longer any doubt about leprosy being an infectious disease, using that term in its widest sense of the passage of the infective lepra bacillus from the diseased directly or indirectly to healthy persons, who have come into more or less close relationship with infective cases, but the precise method by which infection takes place is still not scientifically demonstrated, although most modern authorities on the subject are agreed that the bacillus probably finds entry through minute lesions or abrasions of the skin or of a superficial mucous membrane, while as a rule somewhat prolonged close proximity to an infective leper, usually through living in the same house, is necessary before infection takes place.

Owing to the exceptionally long incubation period of from a few months to many years, and the frequent slow and insidious onset of the symptoms, especially in the nerve form of the disease, in which the bacilli are mainly limited to the nerve trunks producing only loss of sensation and slight discolouration of the skin in the earlier years of the disease, the difficulties in tracing the source of infection in countries where leprosy has long been endemic are commonly insuperable. Would it be easy to prove even small-pox to be infective if it had an incubation period extending from several months to twenty years as in leprosy? When, however, the disease has been recently introduced into a civilised country conclusive evidence of its infectivity is far more evident, as in the Memel outbreak in East Prussia in which no less than 78 cases were traced to five leper Russian servant girls coming from infected parts of Russia to work in families living in the previously uninfected Memel district, and in the Louisiana outbreak in 1870 in a French family, the mother first developing the disease in the most infective ulcerated tubercular form, and within eleven years four of her children, a nephew, an unrelated girl who nursed the mother and an unrelated young man who had slept with the infected fourth son, were attacked and subsequently the disease spread to others and has continued to increase to the present day still mostly among Eurpoeans. Such conclusive examples could be multiplied.

Although leprosy is undoubtedly a communicable disease, nevertheless the degree of infectivity is very slight as compared with most bacterial infections, and in this respect it resembles tuberculosis, caused by a closely allied bacillus distinguishable with great difficulty by microscopical examination, and belonging to the same class of acid-fast organisms. Numerous statistical data show that only from 3 to 5 per

cent. of healthy persons living in the same house as a leper contract the disease, although this proportion is still over one hundred times as high as the general incidence of leprosy in India, for example, the liability being influenced especially by the type of case and by the varying susceptibility to infection at different ages. Thus, the tubercular form of leprosy with extensive modules producing the leonine appearance of the face, and the discharge of enormous numbers of lepra bacilli from the nose and throat on sneezing and speaking, as well as from ulcerated modules, is far more infective than the nerve type with little or no discharge of bacilli from the system; a point which is well illustrated by the fact that of 113 cases I have collected in which the type of the infective case was recorded, no less than 94.7 per cent. were of the modular type, often also called tubercular, although having no relationship to tuberculosis itself. Further among some 4,000 recorded cases I have collected, in which the age at the probable date of infection was determined, in one half it occurred before the end of the 20th year, and in three-fourths before the end of the thirtieth year, after which the susceptibility is comparatively slight, while there is also abundant evidence that children are especially susceptible, Denny's Philippine figures showing that no less that 44 per cent. of children living with one or both leper parents for 7 to 10 years, that is over the ordinary full incubation period, contracted leprosy, although we have seen house infections of the general population are only 3 to 5 per cent; a point of the utmost practical importance from the prophylactic point of view.

Conditions under which Infection most Frequently Occurs.

Bearing the foregoing points in view we may now briefly consider the conditions favouring infection in the light of an analysis I made recently of 700 cases collected from the extensive literature of the last fifty years in which the probable source of infection was traced. Of these nearly one-fifth took place under conjugal (including cohabiting) conditions, another two-fifths had lived in the same house as a leper, one fourth had actually slept in the same bed with a leper before contracting the disease, which, added to the first class, make nearly 30 per cent. of bed infections; and in another fifth infection was got by attending on lepers, usually while living in the same house as the patient, making a total of not less than 70 per cent. of house infections; while in almost all of the remaining fifth there had been close association with a leper, including leper playmates of healthy children, to which the infection of a number of unfortunate European children in the tropics has been traced. The whole enquiry thus confirms the generally accepted view that close contact with a leper is usually necessary before infection takes place, while limited association with an unrecognised leper accounts for a number of cases in which the source of infection cannot be traced.

Certain general conditions also materially influence the spread of the disease, favouring conditions being (1) a low stage of civilisation and hygiene, such as obtained in this country during the leprous Middle Ages and still obtains among the poorer inhabitants of extensive and thickly populated tropical and sub-tropical countries where leprosy is mainly endemic, a most important factor in which is the one roomed huts and kralls, commonly with general sleeping accommodation, of India, China, Africa, etc., making room and bed infections especially liable to occur, while even among the poorer in Norway, the males commonly sleep in one room and the females in another. Thus Hansen recorded that during the frequent social visits it was considered bad form to object to sleeping in the same bed as a leper, and he attributed the decline of the disease among Scandinavian lepers immigrating to Minnesota in the North-Central United States in the temperate zone to their having separate bedrooms or at least beds, in the more commodious houses they constructed. (2) General and sexual promiscuity, so marked during the leprosy epidemic in Hawaii, and in the Middle Ages. (3) Favouring social customs, such as smoking the same pipe and eating out of the same dish. (4) Absence of all fear of lepers, the latter also occurring in Hawaii and many other tropical countries, especially among the Mohammedans in Africa; while, on the contrary, various cruel customs against lepers in Central Africa and elsewhere have been recorded frequently as lessening the spread of the disease; while (5) deficient diet, especially fresh food, probably through lowering the resistance

to infection, appears to be the sole basis of Hutchinson's fish theory of origin, which has ceased to have any believers since his decease, and is quite untenable, having been admitted by the originator as inapplicable to the conditions in Basutoland, where the disease spread rapidly, although fish was certainly not eaten; and, lastly, the closing of leper hospitals and cessation of segregation measures have several times been followed by increase of the disease; the contrary conditions being all unfavourable to the spread of leprosy.

Segregation Methods Correct in Theory but Difficult in Practice.

From what has already been said regarding the conditions under which leprosy is commonly contracted, it will be evident that the now generally accepted view that segregation of lepers is the only way in which the disease is likely to be stamped out is correct, but when we study the more important attempts to carry out this simple theory, we find it presents the greatest possible difficulties in actual practice, mainly on account of the following peculiarities of leprosy as an infectious disease. In the case of such a highly infectious and dangerous disease as small-pox, running a short course with rapid loss of infectivity, it is easy to convince the general population of the value, necessity and practicability of segregation; but it is a very different thing in such a disease as leprosy, the infectivity of which is slight, and not so very long ago a matter of acute controversy, while the duration is anything from a few years to several decades, necessitating life-long separation from friends and relatives, and, consequently, so far from it being easy to obtain the essential co-operation of the people in carrying it out, the greatest opposition is certain to be encountered, especially in these democratic days, as evidenced by Mouritz's statement in his History of Leprosy in the Hawaiian Islands, that "The efforts to stamp out leprosy by segregation have taken on the status of a political football," a condition of affairs that even American control only partially mitigated. Nor is this surprising as long as the usually perfectly innocent contraction of leprosy involves life-long imprisonment with little or no hope of amelioration of the sad lot by effective treatment, as has hitherto been the case; a point I shall return to presently.

An equally serious difficulty is caused by the long incubation period and the common insidious onset of the symptoms, especially in nerve cases, making the detection of the disease in the fairly early, but still infective, stages impracticable as long as the patients have the strongest motives for hiding their misfortune as long as possible, in the absence of any effective method of treatment, for experience of segregation measures in Norway, where they have been far more successful than elsewhere, showed that only one case in five was discovered and isolated within three years of the appearance of the first symptoms, thus accounting for the slow reduction of the disease. In the Philippines and elsewhere, the same difficulties have been encountered, and many cases, often of long antecedent origin, are still being discovered nearly a decade after a large number of the lepers had been isolated in the well-equipped Culion settlement by the American Government, which is not surprising in view of the long incubation and hiding of cases by the native population, so that it is far too early to expect striking results from that important trial, although, judging from Norwegian experience, patient persistence will also, in due time, reap its reward in the Philippines. Even under the unsatisfactory conditions so long prevailing in the Molokai Settlement of Hawaii, the leprosy incidence, which had remained nearly stationary at 10 per mille from 1879 to 1899, fell during the next fifteen years under American supervision to only 2.3 per mille in 1915, or a little over one-fifth of the earlier rate. Segregation measures have been stated by Hutchinson and others to have failed in such countries as South Africa and Crete, but in the former it was officially reported year after year that the accommodation in the Robben Island Asylum was insufficient even for those wishing to be admitted, and far more so for carrying out any compulsory measures, which were not actually enforced; while in Crete the conditions were shown by Professor Ehlers to be worse than useless, for the leper owners of houses in the leper villages close to the main towns were allowed, under Turkish rule, to let their houses to healthy persons, while they went on lucrative begging tours, the so-called segregation places thus actually serving to spread the disease, infections among those taking the leper houses being on record. In other

places vacillating policy, deficient accommodation, want of compulsory powers or political influence preventing such powers being put in force, cessation of prophylactic measures following the unfortunate 1865 report of the Royal College of Physicians of London condemning such measures on the ground, since found to be erroneous, that leprosy was "not contagious or communicable to healthy persons by proximity or contact with the diseased," on the strength of which the Secretary of State for the Colonies ordered that all such prophylactic measures should be stopped, and any laws sanctioning them repealed in British Colonies, have each served to prevent segregation measures being carried out effectively in various parts of the world.

Success of Segregation Measures in Norway.

The methods successfully adopted in Norway are worthy of note, as most careful records were published and cases discovered several years after the first appearance of the disease were tabulated in the years of their commencement, so that most valuable data were gradually accumulated, which demonstrated that new cases began to decrease in from five to ten years after the measures were introduced in 1856, but primarily only in the South-Eastern areas where they alone were at first carried out, while in time it became evident that the new cases occurring were in proportion to the number of infective centres constituted by the remaining unsegregated cases in any district. This proof of the effectiveness of the non-compulsory measures used up to 1885 led to a compulsory law then being passed, and by 1921 the incidence had been reduced to only six per cent. of the numbers in 1856, although there is strong evidence that the disease was then on the increase. Particular attention was paid to isolating the more infective tubercular cases, while a number of the little dangerous nerve cases were allowed to be kept at home with special precautions and under close medical supervision, everything being thus done to mitigate the severity of the measures, and the results show what can be accomplished by persistence in carefully considered prophylactic measures, at any rate in an European race living n the temperate zone, thus furnishing an object lesson for other countries.

Recent Advances in the Treatment of Leprosy.

I now come to the most important part of my subject, namely, the work of the last few years in improving the treatment of leprosy, which opens up a vast field for research, and one not without some bearing on the still more important subject of the treatment of tuberculosis, due to an organism very closely allied to that of leprosy, while there is already evidence that effective prophylactic measures against leprosy will be greatly simplified in actual practice. This advance has been attained through the labours of several research workers, among whom I am fortunate enough to have a place, and its history is briefly as follows. As early as 1854 the attention of English physicians was drawn to an old Indian remedy for leprosy and tuberculosis, chaulmoogra oil, at first erroneously thought to be derived from the seeds of the tree *Gynocardia odorata*, but later shown by Sir David Prain to be from those of the Assam and Burma tree, *Taraktogenos kurzii*, while Philippine observers still later showed that the seeds of various species of Hydnocarpus contained the same active principles, chaulmoogric and hydrocarpic acids, first isolated together with gynocardic acid by Power. The crude oil given by the mouth undoubtedly has a good effect in leprosy, but owing to the difficulty most patients have in taking effective doses for long on account of its nauseating properties, it failed to do more than temporarily retard the progress of typical advanced cases, although Hopkins in Louisiana showed that a certain number of incipient cases might become free from outward signs of the disease. The drug thus failed to be of more than palliative value. Attention was next directed to bacterial injections as the result of the establishment of vaccine immunology by Sir Almroth Wright, and some striking improvements were obtained, which, unfortunately, did not prove to be very lasting in nature. Research once more became directed to the old Indian remedy and efforts were made to find a suitable method of administering it by injection to overcome the limitations of the oral method, a case having been reported from Egypt as early as 1899 of apparent recovery after

a five years' course of such injections, of a painful nature, which few patients are willing to submit to, and in 1914 Dr. Heiser in the Philippines recorded apparent cures of 11 per cent. of a small series of cases treated by this method. In 1915 Dr. Heiser visited me in Calcutta and asked me to take up work at the subject, when I showed him a medical man who had nearly recovered under large doses of gynocardic acid, being the lower melting point fatty acids of chaulmoogra oil, which I had found to be better borne orally and more effective than the whole oil. Three years before I had asked a leading firm of manufacturing chemists if they could make for me a soluble preparation of gynocardic acid suitable for hypodermic injection, but had received a reply in the negative, although I learned subsequently that this actually had been done in the form of sodium salt of gynocardic acid, and a case in South America had been treated successfully by it. With the help of Dr. Chuni Lal Bose, of the Calcutta Medical College chemical laboratory, Sodium gynocardate was made, and I found it to be of value in leprosy subcutaneously, although painful, which limited its practical value. I next ascertained its suitability for intravenous injection by means of a few nearly painless experiments on animals, without which it would have been unjustifiable thus to administer the new drug in man, and found this method of administration to be almost painless and much more efficient, and I very soon obtained local inflammatory reactions in the leprous tissues, with rapid destruction of the causative organisms, such I had not seen previously, and at once realised that an important advance had been made, which I followed up during my last four years in India, and arranged before I left for this research to be continued by a whole-time worker, Dr. E. Muir, and raised half the necessary funds, the other half being provided by the Government of India Research Association. During the next three years, I made a further advance by showing that soluble preparations from other oils, including those of cod-liver oil and soya bean, were also effective in leprosy, to which two others have recently been added by Dr. Muir, and thus I established the important principle that the beneficial effects are not limited to chaulmoogra and hydrocarpus oils with their peculiar types of unsaturated fatty acids, as had previously been thought to be the case, and thus opened out a wide field of research which I extended to the treatment of tuberculosis, although that is a much more difficult subject, which I am still investigating, and with regard to which I can only say here that it has not yet been placed on a footing which will allow of its general use, but requires much further enquiry, which is now being carried out by experts, before it can be recommended for use by others. It is still too early to say if it will prove to be a safe and useful method in that serious and widespread disease. Professor Dean and his colleagues in Honolulu soon confirmed my work and introduced the useful modification of injecting intramuscularly another soluble product he made, ethyl ester chaulmoograte, which had previously been put on the market as a patent remedy by German chemists, and can more simply and rapidly be administered intramuscularly than the sodium salts intravenously, although the latter also sometimes are required in resisting cases. By these methods the leprosy bacilli are gradually destroyed within the tissues and may in time completely disappear, as far as microscopical examinations show, together with all outward signs of the disease. In a few cases I have seen steady progress and complete clearing up after a severe reaction produced by a few intravenous injections, although all treatment was stopped after the reaction appeared, indicating the production in the system of effective resisting powers against the bacillus as a result of the destruction and absorption of very numerous bacilli during the reaction; clearly indicating that an important advance had been made on previous methods of treatment.

This is not a suitable occasion to go into any detail regarding the results yet obtained by the improved methods of treatment, and I am especially anxious to avoid any exaggerated ideas being formed regarding them, for leprosy, like tubercle, is a disease in which it is impossible to say when a real cure has been obtained in the sense of complete eradication of the causative organism from the whole system, and sufficient time has not yet elapsed to say how many of the apparent cures will prove permanent. But it is certain that relapses have occurred not very rarely in patients who left off the treatment against advice as soon as the outward signs had disappeared,

and the relapse of eight per cent. of cases discharged from the Honolulu hospital has recently been reported, so great caution is necessary, and personally I have refused throughout to speak of curing leprosy. Further, as might be expected, better results are obtained in early than in advanced cases, while, of course, no drug can possibly restore the lost fingers and toes of the long-standing mutilating nerve form of leprosy, which constitutes such a large proportion of the helpless cases in leper asylums. Nevertheless, in the largest leper asylum in India, at Purulia, within eighteen months of Dr. Muir introducing the treatment on a large scale, the mortality had been reduced to one-fifth of the former rate, and a very similar result has been obtained in China, many of the patients being able once more to undertake useful work, while the renewed hope held out to these unfortunate people is a factor of great importance, and further progress may still be hoped for from continued research, which has been stimulated greatly in a number of countries by the recent successes.

The Influence of Improved Treatment in Simplifying Segregation Measures.

We have already seen that the greatest obstacle to the effective carrying out of segregation is the difficulty of isolating the early cases, which will continue to form foci for the spread of the disease as long as they have everything to lose and nothing to gain by declaring their disease as hitherto, but now that a treatment is available for both ameliorating their condition and also rendering the disease far less infective by destroying so many of the causative bacilli, and healing the ulcers, the conditions are completely altered, and already, for the first time in the long struggle against leprosy in the Sandwich Islands, numerous early cases have come forward in the more curable stages and asked for the new treatment. The same all-important change is taking place in India and China, in one of the large towns of the latter a missionary doctor being implored by numerous lepers for treatment, while at Dichpali in India successful treatment in the asylum by Dr. Eleanor Kerr has led to many early cases asking for admission. As hitherto such asylums have been mainly refuges for advanced lepers, mostly incurably maimed, but little infective, nerve cases, they have been essentially philanthropic homes keeping these helpless people alive longer than they would otherwise survive by begging, and of relatively little importance as a prophylactic measure, although a humane work of great value, which has not been without some influence on the decrease of leprosy in India shown by the last five decennial census reports; the total numbers returned have declined from 128,089 and 5.9 per mille in 1881 to 102,513 and 0.32 per mille in 1921, the greater relative decline in the rate per mille than in the total number being, of course, due to the population of the census areas having increased from 216,679,331 in 1881 to 318,942,480 in 1921, the actual incidence thus having fallen to little over one-half of the rate fifty years ago. In considering how far these figures show a real decline we must first note that the 1881 census only included a small part of the Native States with a population of almost 20,000,000, which number gradually increased to 72,000,000 in 1921, and as the additional areas were mostly comparatively dry ones with low leprosy rates, a little of the fall in the total figures for India is thus accounted for, and to get a true comparison we must take the following data of the British Provinces, the census areas of which have altered comparatively little in the past fifty years, although, of course, there has been a steady increase in the population and prosperity of the British administered districts:

	British Territory			All India.
Year.	Population.	Lepers.	Per mille.	Per mille.
1881 ..	196,895,542	118,953	0.60	0.59
1891 ..	221,519,797	110,509	0.50	0.46
1901 ..	231,899,507	85,878	0.37	0.33
1911 ..	243,933,178	92,433	0.38	0.35
1921 ..	247,003,293	85,122	0.34	0.32

These figures show a great decrease in the number and rates per mille of lepers in the 1891 and 1901 censuses, a very slight increase in 1911, followed by a slight decrease in 1921, but it appears from the reports that in the first two censuses a considerable number of the harmless cases of leucoderma, which somewhat resembles the early stages of the nerve form of leprosy, and also of syphilis cases, especially in the hills, were erroneously returned as leprosy. Instructions were issued in the later censuses which materially lessened this error, and accounted for part at least of the

decline of the lepers returned in 1891 and 1901: a conclusion which is confirmed by the smaller variations in the last three returns, while the great decrease in 1901 was attributed largely to the especial loss of lepers during the severe famines of the previous decade, especially in Bombay and the United Provinces, and the slight increase in 1911 to the reaction after the previous loss, as there were fewer decrepit lepers left after the famine years to swell the mortality of the next decade, while the slight decrease in 1921 appears to be a genuine one, unless the recent influenza epidemic influenced it.

The 1911 census report points out that while leprosy had decreased by 13 per cent. in two decades the other enumerated infirmities of blindness, insanity and deaf-mutism had remained nearly stationary, and attributed the real diminution of leprosy in part to the rapid increase of leper asylums to 73 by 1911, containing some five-thousand inmates, or 4.7 per cent of the total lepers, while by 1921 the proportion of officially known lepers of the British Provinces in the asylums had risen to 7.7 per cent., the greater proportion of the credit of this advance being rightly attributed to the Mission to Lepers, while some of the provincial reports laid stress on the especial diminution of the disease in some of the worst areas in which leper asylums had been most actively at work. These data are very encouraging, for a steady diminution in the incidence of leprosy has taken place at a time when only a small proportion of advanced, and, for the most part, little infective lepers have been voluntarily isolated, for only a very small proportion came under the limited compulsory segregation of ulcerated begging lepers, who alone could be sent to leper asylums before the recent amendment of the India Leper Act, and could claim their discharge as soon as their ulcers healed under hospital care. How much more might be accomplished by more efficient measures with the assistance to be derived from making full use of the attractive powers and direct benefit of the improved treatment now available?

Leper Colonies versus Leper Asylums.

Most of the Government leper asylums in India are prison-like buildings on very limited town areas, but at an important conference of medical men and superintendents of leper asylums in Calcutta in 1920, I strongly advocated the provision of large leper colonies with ample ground for cultivation in open areas away from towns, more on the lines of the present Purulia leper asylum with its 700 inmates, and others of those under the control of the Mission to Lepers, and this change of policy has been approved by several of the local Governments, who already have plans for establishing them as soon as financial conditions allow. 240 acres have been acquired through the liberality of an European in Bengal, while similar schemes are under consideration by the Governments of Madras and Bombay. The advantages of this policy are especially great in view of the necessity of providing all the inmates with the new treatment, which requires considerable experience and attention to details to get the best results, while the injections have to be continued for many months and in some cases for a year of two, so it is obviously economical to provide accommodation for not less than 1,000 lepers in any colony with its expensive administrative and medical staff, while the provision of ample land for cultivation is more than ever necessary now that it has been found by experience both in India and in China, that many helpless lepers can be restored by the improved treatment sufficiently to allow them to undertake both agricultural and industrial work, greatly to the benefit of the finances of these institutions, which should more than cover the increased cost of the active treatment now necessary. The very depressing prison-like atmosphere of town asylums will also be done away with, and open air life and exercise, which Dr. Muir has shown to be most beneficial as an adjuvant to the treatment, will be secured and a cottage system can be utilised for married patients with the advantages of home life, although all healthy children must be removed from their parents at the earliest possible age on account of their especial liability to infection already pointed out. When leper colonies are provided in every province in India with efficient treatment, and a few recovered patients are able to return to their homes, no compulsion will be required to keep the colonies full, while much earlier cases will come forward with quicker recovery and diminution of the foci of infection in the villages. This must in due time lead to a more rapid decrease in the incidence of leprosy in the Indian

Empire, although it is well to point out in advance that the first effect will be an apparent increase in the number of cases of leprosy due to early cases hitherto hidden coming forward, as there will be no lack of Jonahs to claim this apparent increase as a proof of the failure of the colonies to reduce leprosy, although it will in fact be the first sign of their eventual success, while it must also be remembered that owing to the very long incubation period of leprosy at least a decade or two must elapse before any definite effect is produced in the way of lessening newly-developing cases of the disease.

Owing to the especial susceptibility of the young to infection, children and adolescents should never be allowed to live in the same house with a leper, and infants of leper parents should be removed from leper parents as soon as possible after birth, long experience in India and elsewhere having proved that if they are brought up apart from their parents they remain free from the disease and can safely marry when grown up without their children becoming lepers, and I believe that if infection of the young could be prevented leprosy would rapidly decrease. In Panama the American authorities have successfully introduced the plan of only allowing the marriage of lepers if the man submits to the simple and safe operation of sterilisation, which makes the procreation of children impossible; a practical measure which might well be adopted in all leper colonies and one which would have prevented the recently reported terrible infection of one third of the children born in the Culion settlement while under the Philippine control.

THE PRESENT POSITION OF THE LEPROSY PROBLEM.

Probable Number of Lepers in the World.

A few years ago Dr. Victor G. Heiser, the founder of the famous Culion leper settlement of the Philippine Islands, roughly estimated the number of lepers in the world at two millions, and I have examined the extensive data I have collected recently and worked out the following estimates, in considering which it must never be forgotten that in the tropical and sub-tropical climates, in which nearly all the highest rates occur, the data, mostly compiled by laymen, only include the typical and easily recognised more advanced cases, while the earlier ones can only be detected by medical men with some actual acquaintance with the disease, so that to get the real numbers the figures I am giving have to be doubled, and, judging by recent Indian experience, this will still give an underestimate of the real numbers, for I am in agreement with Muir in thinking that there are probably about half a million lepers in India at the present time, although only 102,000 were returned at the last census, the deficiency being especially among females, in whom the disease is more easily hidden. The following are the most important figures from my tables:

Europe, 7,044, including in South Russia 1,200; the Baltic Provinces, 1,000; Turkey, 600; Crete, 1,000; Roumania, 551; Spain, 522; Portugal, 466; and fewer elsewhere.

Asia, 1,256,877; including India, 102,503 (an underestimate); China, 1,000,000 (a rough guess by one writer, but probably not very far out); Japan, 102,585; Indo-China, 15,000; Philippines, 4,000; Siam, 14,000,; Java, 4,443; Sumatra, 1,448, etc.; Straits Settlements and Malay States, 1,145; Palestine, 600; Ceylon, 589; and Persia. 150.

Africa, 525,800, of whom the immense majority, which I have estimated from recorded rates per mille and populations at 509,302, occur in Tropical Central Africa, which the map I have shown demonstrates to contain by far the most extensive areas of the very high leprosy incidence of 5 to 60 or more per mille, Egypt, 6,513; Madagascar, 4,200; Nyasaland, 1,608; and South Africa with Natal, 3,640; and Mauritius, 536. As the rates per mille for Central Africa have been calculated from the number of lepers found among a few thousand of the population collected for vaccination or other purpose, the figures can only be relied on to show that leprosy is very common there. So Africa, China, Japan and India include the great majority of the lepers in the world.

South America, together with the West Indies, 23,784, including Brazil, 15,000; Colombia, 4,304; Dutch Guiana, 2,000; French Guiana, 573; Venezuela, 582; Argentina, 730; British Guiana, 387; British West Indian Islands, 1,047; Cuba, 1,500, etc.

North America has comparatively few lepers, the numbers in Mexico being unknown, while those in the United States have been variously estimated at between

146 and about 1,000, the latter being nearer the truth.

Oceania shows some very high rates per mille, but owing to the small area of the Islands, the total number in my tables only amounts to 4,617.

Australia has very few lepers, segregation measures having been more strictly enforced there than anywhere else in the world; tropical and sub-tropical Queensland are the only part where the disease is endemic to any appreciable extent in the coast districts, which also show the heaviest rainfall of the continent, having 21 isolated lepers in 1913.

The above figures omit a number of countries with no available figures, yet they total 1,718,600, or very near Heiser's estimate of 2,000,000, and if early cases could be included, a total of 3,000,000 would easily be reached, so the gravity of leprosy as a world problem can hardly be exaggerated, although there appears to me to be little evidence that it is actually spreading to any extent at the present day, except perhaps, with the spread of Mohammedanism in Central Africa, and, according to one writer, in Brazil.

The Leprosy Problem in the British Empire.

The figures just given suffice to show that there is no early prospect under present conditions of appreciably reducing the terrible prevalence of leprosy in Central Africa and in China, although the Mission to Lepers is doing a great deal in the latter country. It is to the British Empire, which is already doing more for its lepers than any other extensive country in the world, that we must look to set an example in this matter, so in conclusion I wish to point out the places in which it should be possible to apply the new knowledge without undue delay to the solution of the hitherto almost insoluble problem of materially reducing and eventually stamping out the most cruel and loathsome disease the human race is heir to. India, from whence much of the recent advances has emanated, is alive to the present necessities, as I have already shown, but leper colonies with proper modern treatment should also be practical in the West Indian Islands and British Guiana, in which the lepers now known do not exceed about 2,000, although early unrecognised cases would doubtless at least double that number. The present policy of separate small and relatively ill-equipped and staffed isolation stations should be abandoned in favour of one or two large establishments jointly financed by a number of the small Island Colonies, with ample ground and efficient medical staff. In South Africa, again, the prison-like Robben Island, although presenting some advantages, should be supplemented or largely replaced by an agricultural colony, with sufficient accommodation to admit all the leprosy cases which, indeed, would only be a reversion to the policy between 1817 and 1885, when the Cape lepers were segregated in a beautiful valley in the Caledon district some distance from Cape Town, while the admirable work which has recently been done in Basutoland by Dr. Long, might be extended to other native areas. In our tropical African colonies the large number of lepers and financial stringency make the problem far more difficult, but the sooner a commencement is made on the lines here advocated the better. In Fiji compulsory segregation has already been in force in a leper asylum since 1911, in Mauritius there is also an asylum, but many lepers apparently remain free, some of whom would no doubt be attracted, by prospects of effective treatment, and the same remark applies to the British possessions in the Malaya Peninsula, where my treatment has recently been introduced and other tropical and sub-tropical colonies which it would take too long to deal with individually.

CONCLUSIONS.

I must now draw this lengthy communication to a close by stating the conclusions the evidence now appears to me to warrant with regard to a more hopeful outlook on the ancient problem of leprosy.

(1) A long controversy, which did much to retard prophylaxis against leprosy all over the world, has been settled by every important leprosy conference of the last three decades being almost or quite unanimous in regarding leprosy as a communicable disease, for which isolation of the infective cases is the only practical preventive measure, but one which the experience of Norway conclusively shows is effective wherever it can adequately and persistently be carried out.

(2) Hitherto the want of an effective treatment of the disease has led to the

inevitable concealment of the early not easily recognisable, but infective, stages of the disease as long as possible, to save the patients from life-long incarceration, without hope of amelioration of their unfortunate lot, or material prolongation of their miserable lives, with the result that in most tropical and sub-tropical climates, with greater tendency to spread of the infection than in the temperate zone, segregation measures have too often failed, to a large extent, in controlling and reducing the disease.

(3) Within the last few years, modern researches have greatly improved the effectiveness of the treatment of leprosy and opened a new field of research promising still further advances in this greatly desired direction, and although it is still too early to claim permanent cures, yet a few typical cases treated by me have now remained free from all signs of the disease for at least five years, while the infectivity of the disease is greatly reduced or completely removed in successful cases; and already in several widely separated endemic areas early cases of the disease, previously hidden away, are coming forward in large numbers and asking for the treatment for the first time in the history of leprosy. This will greatly facilitate prophylactic measures in the near future, thus opening out a new era of hope in the control of perhaps the greatest calamity that affects mankind.

In 1889 the death of Father Damien from leprosy, after many years' devoted service among the lepers in the Molokai Settlement of Hawaii, sent a thrill through the civilised world, although he was only one of many such martyrs, including several medical men, and his death led to the formation of a National Leprosy Fund, under the Presidency of the late King Edward VII., when Prince of Wales. One of the principal outcomes of this was the Indian Leprosy Commission, followed by a great extension of leper asylums in India and elsewhere. Although the recent advances in the treatment of leprosy may be less sensational, I suggest that they present a far more important and practical epoch in the history of leprosy, and one that should be taken advantage of without further delay for the inauguration of a new effort to apply to leprosy the eminently practical saying of King Edward: "If preventable, why not prevented?"

[The Society is indebted to the Royal Society of Tropical Medicine and Hygiene for kindly permitting the reproduction of the map shown on page 453].

DISCUSSION.

MR. CHAO HSIN CHU (Chinese Chargé d'Affaires) said that until he heard the paper that afternoon, he had not fully realised the importance of the leprosy problem. He had been convinced, however, by what Sir Leonard Rogers had said, and by his statistics, maps and photographs, that it was indeed a grave and urgent problem, and he would not fail to call the attention of the authorities and medical men of his country to the necessity for doing their best to co-operate with other countries in fighting the disease.

MAJOR-GENERAL SIR RICHARD HAVELOCK CHARLES, G.C.V.O., said the people of this country should congratulate themselves on the fact that the problem of leprosy did not concern them personally. There was a time, however, when there were enormous numbers of lepers in England, and he believed a leper asylum once stood on the site now occupied by St. James's Palace. Sir Leonard Rogers had shown that there was now some hope for the leper, whereas formerly there was none. At the same time, it should be understood that although a leper might be said to be cured, he could not really be regarded as being so until five years or more had elapsed after the disappearance of the disease, and until he had been examined by a medical man with experience in the matter. It was well-known, however, that nowadays even bad cases of leprosy could be improved. That had had a good effect in encouraging the early cases to submit themselves voluntarily to treatment; and for the early cases much could be done. The progress of scientific research had of late years been very great in India, largely thanks to the efforts of Mr. Chamberlain and particularly to those of Mr. Montagu. Research schools had been started and the Calcutta School of Tropical Medicine was now the finest of its kind in the world: the greatest praise was due to Sir Leonard Rogers for his help in making it so. There was in India an officer formerly known as the Sanitary Commissioner, but now called the Director of Public Health. That re-christening had had a most unfortunate effect, because it was now proposed that his office should be abolished. The ship of public health was, he feared, very likely to strike upon the rock of disease if the bell which gave warning of its presence was removed; the rock of disease was like the Inchcape Rock, and the man who was wielding the axe in India would have cause to behave like Ralph the Rover in the poem, who

> ". . . . . . tore his hair
> "And cursed himself in his despair,"

if the removal of the bell had similar consequences, and the public health of India deteriorated. He was very glad to see the Parliamentary Under Secretary of State for India in the chair, and hoped he would aid in defeating the retrograde step in question. He (the speaker) had the honour of representing India in the Health Section of the League of Nations and in the International Society of Hygiene in Paris. When countries so far apart as Persia and Peru had Ministers of Health, how could he go to those bodies and tell them that the post of Minister of Health in India had been abolished?

THE CHAIRMAN said in reference to Sir Richard Havelock Charles's appeal that while it would obviously be improper for him to express his personal views on the subject in question, he thought he might say with certainty that his noble friend the Secretary of State would give the most careful consideration to the views which had been expressed on the matter. It would not be altogether in accord with the state of public opinion generally that any office which had done so much for the well-being of the people of India should be abolished. His own personal inclination would be against the abolition of anything which tended to promote the public health, more especially since for the last ten years he had had the honour of being chairman of a London hospital, and had thus gained a certain amount of inside knowledge concerning the struggle against disease.

SURGEON W. W. KING (United States Public Health Service) said he had been interested in the subject of leprosy for a long time past, and had had a good deal to do with it; but he had seldom had the pleasure of hearing so lucid and interesting an address on the subject as that which had been delivered that afternoon. It would give him no little pleasure to send an account of it to several officers in his own service whose interest in the struggle against the disease was intense, and he knew it would be greatly appreciated by them. Leprosy existed in the United States to a limited extent, and more generally in the Philippines and Hawaii, where it was being dealt with in a fairly efficient manner. There were leper colonies in Porto Rico and the islands acquired from Denmark during the War with which he personally was acquainted. In all those places the chaulmoogra oil treatment was being carried out, and the men on the spot were very enthusiastic about the results they were obtaining. It was a fact of tremendous importance that a disease which, since the dawn of history, had been regarded as the most horrifying, fear-creating disease known, should now be on a fair way to being conquered. If no further progress was made, at any rate a stage had been reached when the fear it formerly created was no longer justified. That constituted a triumph for medicine, and, by reflex action, would allow medicine to go ahead against other diseases which had no relation to leprosy. Great credit and great admiration were due to the reader of the paper for his work in that direction.

MR. W. H. P. ANDERSON (General Secretary of the Mission to Lepers) said that to those who, for many years past, had been dealing with the problem of leprosy and seeking its solution, what Sir Leonard Rogers had said that afternoon came as a breath of fresh and invigorating air. Both personally and on behalf of the Society he represented, he would like to say how much they owed to the help they had received from the research work of Sir L. Rogers. He was not a scientist only, but a man with a great fund of sympathy for, and understanding of the mind of, the leper, and that had contributed largely to the success of the work which was now being carried on in continuance of his efforts. The Mission to Lepers was greatly indebted to Sir Leonard, and to Dr. Muir, who succeeded him. Too little was known of what the Government of India and the Provincial Governments were doing in the fight against leprosy. The Government of India had dealt with the question in the broadest possible manner, bringing to it not only sympathetic consideration, but practical help. The outstanding feature of their work in recent years was the revision of the Indian Leper Act, which had enabled an immense step forward to be made. They had also made generous grants for research work, by which the Society he represented had benefited, since its workers could be sent to Calcutta and trained in the use of the latest methods of treatment; and that had had its effect throughout the areas served by their asylums. The Provincial Governments had not "axed" their grants for care and segregation work, which had been continued, and which had, he believed, the deepest sympathy of the Indian Ministers. With regard to the latest development mentioned in the paper, the institution of Provincial settlements for the care of lepers in India, he was very glad that the old methods of compulsion were to cease: they had never been looked on with favour by any one. Internal attraction rather than external compulsion was to be relied upon in future, and those who had been dealing with the problem believed that once the institutions in question were in working no policemen would be needed to keep the lepers in, though some assistance might be required in keeping them out! He believed the problem of leprosy in the British Empire would be fought out and solved in India. What India did would be done elsewhere: if success were met with by following the lines now being adopted in India, the same success would be obtained in other parts of the Empire, where

the disease was, unfortunately, so prevalent at the present time. The key-note of the Mission to Lepers had been to secure the co-operation of the leper himself. Few people realised the importance of that; too many had the Old Testament idea in their minds, and thought the leper should be dealt with by segregation and compulsion; but it had now been found that, if one treated him as a brother-man, unfortunately afflicted with disease, but who had committed no crime against society, a tremendous step forward could be made. All who were engaged in the fight against leprosy would be grateful for the splendid help they had obtained from the work which had been so wonderfully, devotedly and generously carried out by Sir Leonard Rogers.

The Rev. Frank Oldrieve (Calcutta) said Sir Leonard Rogers had rendered him personally very great help in the past, but he had never felt so much in his debt as he did that afternoon, because he thought that never before had such a paper on the subject of leprosy been read to any audience. He would like to stress the fact that the problem was one which was now capable of solution; he was convinced that leprosy in India could be abolished in thirty years if the methods now being followed were developed —if, for example, the number of large institutions such as those belonging to his own Mission (the Mission to Lepers) was increased. Those institutions already contained several thousands of voluntary inmates; the people crowded into them. If their number could be increased, and if, in addition, the Provincial Governments would start their own settlements for compulsory segregation, and the latest treatments were used at clinics and all the large hospitals, and the help of the Government of India Publicity Department were obtained (Dr. Rushbrook Williams had promised that if a pamphlet were prepared he would broadcast it throughout the country) the disease could, as he had said, be stamped out in thirty years. He had just returned from India, having visited 22 leper asylums during the past six months. In 14 of those the latest treatments were being used. He had seen over 1,100 cases which had been treated by the new methods, and the majority of them were recovering. Although, probably, he talked and preached about lepers more than any one else in India, he never used the word "cure;" but there was no doubt that they were recovering. At Purulia, where there were 700 lepers, the deaths had fallen in a few years from 22 a month to just over four, and in another asylum the superintendent told him that the lepers refused to pay any more money to the burial fund, because, they said, "Nobody dies here now." There were 260 lepers in that asylum, and they were all, he thought, recovering. At the asylum at Nasik, 60 to 70 per cent. of the lepers wore bandages on their hands or feet, because they were so troubled with ulcers, sores and so on; but at Dichpali, where there were 260 inmates, very few wore bandages, and the English nurse in charge told him that her dressings did not take more than twenty minutes a day for all that number of people. A story was told that a missionary recently came across some of those people holding a thanksgiving meeting to praise God, for that once again they could feel prickly heat! That meant, of course, that the anæsthesia was passing away, and that life and hope were, therefore, returning to them. As time went on the leper community would be more and more grateful to Sir Leonard, whose treatment was producing such wonderful results; personally, he firmly believed that, perhaps after some slight alterations, it would turn out to be a cure, and by its aid and by segregation leprosy could be got rid of throughout India.

The Chairman, before calling on Sir Charles Yate to propose the vote of thanks, said both the paper and the discussion had been most interesting, and a feature of both paper and discussion had been their hopefulness. It seemed that the whole trend of expert opinion, as expressed that day, was that science (aided, he was glad to think, by Governments within and without the British Empire) was at last gripping the dreaded scourge of leprosy by the throat. Those who, like himself, were not experts, would go away from the meeting with a feeling that much had been done in the last few years, and that, although much remained, science was on the high road to deal with it. He would like to thank Mr. Anderson for his remarks about the Government of India and the Provincial Governments in that country. It would give him much pleasure to call the Secretary of State's attention to what had been said, and he was sure the Government of India would like to be informed of the tribute which had been paid to them. Mr. Anderson's remarks in that connexion fortified what Sir Richard Havelock Charles had said as to the abolition of a certain office. He believed his name was to be coupled with that of the lecturer in the vote of thanks, and, therefore, he would like to say what a pleasure it had been to him to preside that afternoon, a pleasure which was greatly enhanced by the beautiful meeting room the Society possessed—one of the most beautiful of its kind he had seen. He had never been able to understand why, in the Victorian Age, the most hideous decorations obtainable were always selected for such rooms: he had sometimes attended lectures, in themselves excellent, which had been completely spoiled by the surroundings in which they were delivered. He was pleased to see the Society had recently re-decorated its premises, and must congratulate it on the result. He

was reminded by the Secretary that an ancestor of his was amongst the earliest members of the Society, and had what was probably the unique honour of receiving no less than four gold medals – one in 1761 for sowing twenty acres near Plaistow with acorns, another in 1767 for planting 2,000 small leaved elms in Ash Park, Sussex, and the other two in 1776 for sowing acorns and planting Lombardy poplars. So far as the elms were concerned, he (the Chairman) was obliged to add that only one of the trees had survived, the soil being unsuitable for anything but oaks.

Colonel Sir Charles E. Yate, Bt., C.S.I., C.M.G., M.P., in proposing a vote of thanks to Sir Leonard Rogers for his extremely earnest and illuminating paper, and to Lord Winterton for his kindness in presiding, said the paper gave a very clear statement as to the present position of the problem with which it dealt. A previous speaker had said that the problem would be solved in India, and that India's lead would be followed by other countries. He trusted that would be the case. In 1913 he was asked to raise in Parliament the question of leprosy in England, his informant telling him that he feared the disease was steadily creeping into the East End of London. Mr. John Burns, the then President of the Local Government Board, told him in reply that so far as he knew there were only a few cases in this country, and that the disease was not spreading, but that the whole question was under consideration. In 1917 he heard from the Company of St. Giles's, which took an interest in the matter and had a home for lepers, that there were about fifty of them in the country, many being old civil servants and soldiers who had contracted the disease in the East. The plight of lepers here, it was said, was pitiable beyond description. Disabled from earning a living, cruelly disfigured, they were debarred from admission to Poor Law infirmaries, or to ordinary charitable institutions. During last year he had put three questions on the subject in the House of Commons, inquiring whether the disease was notifiable or not, and also asking the Under Secretary of State for India for an account of the results of the Leper Act passed by the Imperial Legislative Council of India. He received a most illuminating account of the results so far obtained, which he believed had been published in the Press. Finally he had asked whether the Minister of Health would consider the question of making the disease notifiable in view of the fact that cases of leprosy in this country were reported to have been contracted abroad, and that there was no definite information as to the number of such cases. That had not so far been done in this country, but he thought it should be, so that the unfortunate sufferers might be given a chance of recovery. Lepers in England should have the same chance in that respect as lepers in India, where the treatment described by Sir Leonard Rogers had had such promising results.

Sir Charles S. Bayley, G.C.I.E., K.C.S.I., in seconding the motion, said he was the more glad to do so as he was at present Chairman of the Indian Section of the Royal Society of Arts, and could, therefore, say in the name both of the Section and the Society, how grateful they were to Sir Leonard Rogers for the paper which had been read and to Lord Winterton for presiding. To any one who, like himself, had spent the best part of a life-time in India, there could be no subject with a sadder interest than leprosy. During his earlier years in India it was sadder than it was at present, for, as the Chairman had said, the prevailing note that afternoon had been one of hopefulness. When he was first appointed an Assistant Magistrate he was sent to distribute alms to lepers at a mosque in the suburbs of Calcutta: about 500 rupees a month had been left by a Mohammedan Prince of the Mysore family for that purpose. A more painful sight he had never witnessed; most of the people had bandages on their fingers and toes, many had no fingers or toes to bandage, and some had no hands. There seemed, at that time, to be no hope for any of them. Seven or eight years ago, shortly before he left India, he had the good fortune to be Lieutenant-Governor of Bihar and Orissa, the province in which Purulia was situated. It was wonderful to see what was being done for the lepers there, and to notice their general contentment. There was no compulsion exercised, but they were only too glad to stay. The treatment then in force was giving satisfactory results; the appearance of the lepers was being improved, and in many cases the anæsthesia was disappearing. There was not, however, the hopefulness which had permeated the proceedings that afternoon. To-day we seemed to be on the eve of very vast improvements, and we could look forward to the fulfilment of the prophecy that, with care, the disease could be eradicated in thirty years, or even in fifty or sixty years, it would be a tremendous achievement.

The vote of thanks was carried unanimously.

Sir Leonard Rogers, in his reply, assured Sir Charles Yate that there was little danger of leprosy spreading in this country. In the temperate zone, given good sanitary conditions, the disease did not tend to spread. The only case of infection recorded in this country during the last fifty years was that of an Irish soldier from India, whose brother slept with him in the same bed for eighteen months. That was asking for it! Similarly,

170 Norwegians developed leprosy shortly after arriving in Minnesota, and Hansen, the great Norwegian authority, went over to investigate the matter, but he could not trace a single case of infection being conveyed from those people. Given good sanitary conditions and a good climate, the disease tended to die out. Although there were a few cases in this country, they were receiving proper treatment.

The meeting then terminated.

GENERAL NOTE.

ROYAL INSTITUTE OF BRITISH ARCHITECTS.—In view of the very great interest taken in the Exhibition of Mr. William Walcot's Drawings, "Some Great Temples of Antiquity and Roman Compositions," which is being held at the Royal Institute of British Architects, 9, Conduit Street, W.1, arrangements have been made to keep it open until further notice. The general public are admitted free from 10 a.m. to 6 p.m. (Saturdays 10 a.m. to 1 p.m.)

MEETINGS OF THE SOCIETY

ORDINARY MEETING.

WEDNESDAY, MAY 30, at 4.30 p.m.—A. J. SEWELL, "The History and Development of the Perambulator and Invalid Carriage."

DOMINIONS AND COLONIES SECTION.

TUESDAY, JUNE 5th, at 4.30 p.m.—SIR EDWARD DAVSON (President of the Associated West Indian Chambers of Commerce; Chairman of the British Empire Sugar Research Association, Vice-President of the British Empire Producers' Organisation.) "The Economic Conference and Crown Colony Development." His Grace the Duke of Devonshire, K.G., G.C.M.G., G.C.V.O., P.C., Secretary of State for the Colonies, will preside.

INDIAN SECTION.

Friday afternoons.

JUNE 1, at 4.30 p.m.—AUSTIN KENDALL, I.C.S., rtd., "The Participation of India and Burma in the British Empire Exhibition, 1924." SIR CHARLES C. MCLEOD, Member, Board of the British Empire Exhibition, will preside.

JUNE 15, at 4.30 p.m.—SIR JOHN H. MARSHALL, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture.) The Most Honourable The Marquess Curzon of Kedleston, K.G., G.C.S.I., G.C.I.E., P.C., F.R.S., will preside.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

TUESDAY, MAY 22..University of London, University College, Gower Street, W.C., 5 p.m. Prof. G. D. Hicks, "Kant's Theory of Beauty and Sublimity." (Lecture II.)
At King's College, Strand, W.C., 5.30 p.m. Dr. H. W. Carr, "Blaise Pascal: Tercentenary of his birth, June 19, 1923." (Lecture III.)
Royal Institution, Albemarle Street, W., 3 p.m. Prof. Flinders Petrie, "Discoveries in Egypt." (Lecture I.)

WEDNESDAY, MAY 23..Massage and Medical Gymnastics, Society of, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 6 p.m. Dr. G. R. Girdlestone, "Living Anatomy, or Rules of Life in Cell Communities."
University of London, University College, Gower Street, W.C., 5.15 p.m. Sir Thomas Holland, "Phases of Indian Geology." (Lecture II.)
At King's College, Strand, W.C., 5.30 p.m. Prof. W. S. Holdsworth, "Sir Matthew Hale."
At King's College for Women, 61, Campden Hill Road, W., 4.30 p.m. Prof. V. H. Mottram, "Nutrition." (Lecture VII.)
Literature, Royal Society of, 2, Bloomsbury Square, W.C., 3.30 p.m. General Anniversary Meeting.
5 p.m. Ordinary Meeting.

THURSDAY, MAY 24..London Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5 p.m. Colonel Sir Arthur Holbrook, "Scavenging the Sky."
Illuminating Engineering Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 8 p.m.
University of London, University College, Gower Street, W.C., 5.30 p.m. Mr. A. del Re, "Tasso's *Aminta* and the Italian Pastoral."
At King's College, Strand, W.C., 5.30 p.m. Dr. O. Vocadlo, "Czechoslovakia." (Lecture III.)
At the Royal Society of Medicine, 1, Wimpole Street, W., 5.15 p.m. Dr. E. D. Wiersma, "The Psychology of Epilepsy."
Royal Institution, Albemarle Street, W., 3 p.m. Prof. E. G. Coker, "Engineering Problems." (Lecture II.)
Optical Society, at the Imperial College of Science, South Kensington, S.W., 7.30 p.m. Mr. D. Baxandall, "Telescopes from a Historical Standpoint."
Linnean Society, Burlington House, Piccadilly, W., 5 p.m. Anniversary Meeting. Presidential Address.

FRIDAY, MAY 25..University of London, University College, Gower Street, W.C., 5 p.m. Prof. C. Spearman, "Psychology as a Career."
At King's College, Strand, W.C., 5.30 p.m. (Shakespeare Association.) Mr. Bernard Shaw, "The First Folio and the Elizabethan Stage."
At the School of Oriental Studies, Finsbury Circus, E.C., 5 p.m. Dr. P. Giles, "The Aryans." (Lecture II.)
Royal Institution, Albemarle Street, W. 9 p.m. Sir Aston Webb, "The Development of London."
Physical Society, at the Imperial College of Science, South Kensington, S.W., 5 p.m.

SATURDAY, MAY 26..Royal Institution, Albemarle Street W., 3 p.m. Mr. J. B. McEwen, "Musical Education." (Lecture II.)

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

NOTICES.

NEXT WEEK.

WEDNESDAY, MAY 30TH, at 4.30 p.m. (Ordinary Meeting). SAMUEL JAMES SEWELL, "The History and Development of Children's and Invalids' Carriages." L. BERESFORD SEYLER will preside.

FRIDAY, JUNE 1ST, at 4.30 p.m. (Indian Section.) AUSTIN KENDALL, I.C.S., retd., "The Participation of India and Burma in the British Empire Exhibition, 1924." SIR CHARLES C. MCLEOD, Member, Board of the British Empire Exhibition, will preside.

TWENTY-FIRST ORDINARY MEETING.

WEDNESDAY, MAY 16TH, 1923; SIR MALCOLM DELEVINGNE, K.C.B., Assistant-Under Secretary of State, Home Office, in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Edwards, Norman F., London.
Walker, Hiram H., Ontario, Canada.

The following candidates were duly elected Fellows of the Society:—

Anthony, Harvey Mitchell, Indiana, U.S.A.
Finch, Rev. Frederick Stephen, Bunbury, West Australia.
Girand, James B., Mem.Am.Soc.C.E., Arizona, U.S.A.
Khairpur, His Highness Mir Ali Nawaz Khan of, Sind, India.
Notvest, G. Robert, Assoc.Mem.Am.I.E.E., Cleveland, Ohio, U.S.A.

A paper on "Industrial Lighting and the Prevention of Accidents" was read by MR. LEON GASTER.

The paper and discussion will be published in a subsequent number of the *Journal*.

PROCEEDINGS OF THE SOCIETY.

SIXTEENTH ORDINARY MEETING.

WEDNESDAY, MARCH 21ST, 1923.

PROFESSOR E. H. STARLING, C.M.G., M.D., Sc.D., F.R.S., in the Chair.

THE CHAIRMAN, in introducing the lecturer, said the subject of colour vision presented so many points of interest to both scientists and laymen that the Society was to be congratulated on securing a paper which would give one clearer ideas as to what was at the root of our appreciation of colour, and was fortunate in having for its author a man who had devoted his whole life to the subject of colour vision.

The Paper read was:—

SOME CURIOUS PHENOMENA OF VISION AND THEIR PRACTICAL IMPORTANCE.

By F. W. EDRIDGE-GREEN, C.B.E., M.D., F.R.C.S., Special Examiner and Adviser to the Board of Trade on Colour Vision and Eyesight.

HOW WE SEE.

The eye is like a small camera with a complete photographic apparatus. The formation of the image by means of the refracting media of the eye has been very thoroughly worked out. We are only concerned this evening with the photographic film.

You will see in the representation, a section of an eye, which has been thrown upon the screen, that there is a membrane lining the back of the eye. This membrane is called the retina, and it is upon the outer layer of the retina that the images of external objects are formed. The outer layer is the layer of the retina which is furthest away from the front of the eye, so that light has to pass through all the other layers before it reaches the sensitive portion. This

sensitive layer consists of two elements, which are called respectively, on account of their shape, the rods and cones. You will notice a little dip in the centre of the retina: this is the fovea, and it is the region of most distinct vision. In the fovea only cones are present. Outside the fovea the rods are arranged in rings round the cones, and the number of rods to cones increases as portions of the retina further from the fovea are taken, except at the extreme periphery, where, again, only cones are found. In the outer segment of each rod there is a rose-coloured substance, the visual purple, which is photo-chemically sensitive to light. This visual purple is not found in the cones, but only in the rods. It was for this reason that it was not considered to be essential to vision because it was absent from the cones, and only cones are to be found in the fovea, the region of most distinct vision. The rods and cones project into a thin layer of fluid, which is kept in its place by a membrane, the external limiting membrane.

The Distribution of the Visual Purple.

The visual purple is found exclusively in the rods. It does not follow from this, however, that it is not to be found in regions of the retina in which there are only cones, because the external segments of the rods are dipped into the fluid, which surrounds both the external segments of the rods and cones. The visual purple can, therefore, diffuse into this fluid and become distributed to every part of the outer layer of the retina. I have found the visual purple between but not in the cones of the fovea. When the retina was first examined the fovea was the reddest part of the whole retina.

Kühne also found the visual purple in a fluid form in one case, but he did not recognise the significance of the observation. He writes: "In one of these eyes which had been laid open in the dark for an hour, I saw to my great surprise the whole of the retinal mass flooded by a clear purple solution which, when poured upon a plate, exhibited the same behaviour as to light as the mass itself." This refers to the retina of a shark.

The Regeneration of the Visual Purple.

The visual purple is regenerated by the pigment cells of the retina, and this will take place in an eye which has been removed from the body, the bleached retina being again laid on the pigment cells. Victor Bauer finds that not only is the visual purple decomposed and regenerated in daylight, but that light is plainly a stimulus for its regeneration. In fact, he finds with a suitable light that an intensity can be found by which the regeneration of the purple colour in an eye which is exposed to light is clearly more rapid than in an eye which is kept in the dark. The experiments were made with frogs and white rabbits. Two similar animals were taken and their visual purple bleached by exposure to direct sunlight, one was then placed in a dark room and the other left with its eyes exposed to light of moderate intensity, either daylight or the light from a glow-lamp. When the retinæ of both were examined and compared, it was found that the purple colour was more definite in the eye which had been kept in the light.

Optograms.

Kühne found that he could take photographs with a rabbit's eye by means of the visual purple. A window with its bars was focussed on a rabbit's retina. This was left from two to seven minutes. Then on examination the parts of the retina corresponding to the light parts of the window were bleached, whilst that corresponding to the bars of the window and frame was only slightly affected. This image was then fixed by drying, which greatly retards the bleaching of the visual purple.

There is every reason to believe that the means by which light stimulates nerve endings is through a photo-chemical reaction. It is found that the visual purple has properties which are in extraordinary coincidence with certain aspects of vision. If curves be formed giving the amount of energy just sufficient to excite vision, the bleaching effect on the visual purple and the amount of light absorbed by the visual purple at different wave-lengths, it will be found that the three curves follow the same course.

The decomposition of the photo-chemical film, sensitised by the visual purple, stimulates the ends of the cones and a visual impulse is set up which is conveyed through the optic nerve fibres to the brain. The cones corresponding to the light parts of the photograph are those which are stimulated. The function of the rods is to regulate the supply of visual purple to the film in accordance with the amount of light falling upon the eye.

Dark Adaptation.

As visual purple is formed more rapidly under the stimulus of light it must have a function in ordinary vision; when the light is diminished, though less visual purple is formed, much less is used up and so it accumulates, the photo-chemical film becoming more and more sensitive.

There are two methods of scientific investigation, the first being the collection of new facts by special methods and the second that of testing an explanation or theory by ascertaining whether certain facts which should exist if the theory be actual fact are to be found. The theory of vision given not only explains all the known phenomena of vision but numerous new facts predicted by it. (1) The visual purple should be found between but not in the cones, in the rod free portion of the retina. (2) The visual purple should be found in a liquid form. (3) The rod free portion of the retina should be blind when not supplied with visual purple. (4) There should be evidence that the rod free portion of the retina is sensitised from the periphery. (5) All the phenomena which are found with the periphery should be found with the rod free portion, but in a diminished form. (6) As the photo-chemical stimulus is liquid there should be evidence of movement of the after-images in the retina. (7) There should be evidence that the visual purple is regenerated more quickly under the stimulus of light than in darkness.

There are numerous ways in which photo-chemical currents can be seen in the retina. The last movement is a whirlpool movement in the centre of the field of vision. These currents move a positive after-image in the field of vision. Those who are not physiologists must not mistake the movement of an after-image which is due to the movement of the eye for that due to the retinal currents. When, for instance, an after-image of the sun has been obtained this after-image apparently changes its position with the movement of the eye. For instance, if the eye has been looking forwards, on looking upwards the after-image appears to rush upwards, but though movement of the eye does move an after-image in the sense of moving it in the retina the main movement in the above case is only due to the fact that the eye has moved, the relative position of the after-image remaining nearly the same. The actual movement of the after-image in its relative position in the field of vision is probably due to the muscles of the eye compressing the eye-ball and squeezing the photo-chemical film.

Certain Phases of the Positive After-Image.

If two rectangular strips of white paper about three inches long and a third of an inch wide be placed on a piece of black velvet and separated by a distance of an inch, definite positive after-images may be obtained of the two strips by viewing them with one eye, the eye being directed to a point midway between the two strips of paper, the other being closed and covered with black velvet, for the shortest possible time the eye being simply opened and closed. Two clear cut positive after-images will first be seen; these rapidly become blurred and gradually approach each other, the central portions of each appearing to bulge towards each other and to combine first; the upper and lower portions disappear first, the two after-images gradually combine in the centre of the field of vision, the last phase being a white circular blur, which slowly disappears with a whirlpool movement. It will be noticed that the after-images do not become negative.

There is a very distinct difference in effect between moving the eye from one object to another and moving an object in front of the eye. If the hand be moved slowly in front of the eye a blur is seen following the hand, but in moving the eye much more quickly from one object to another no blur is seen in ordinary circumstances. The old photograph is washed out and attention paid to the new photograph.

Professor Andrade has devised two very pretty methods of showing the movement of the after-images. If two cardboard heads, which may be easily made by cutting them out of white cardboard (one may be made to represent a man, another a woman), be viewed in a dim light with a black background, with an interval of two inches between them, at a distance of about ten feet, the eyes being directed at a point between the two heads, it will be noticed that the two heads gradually approach each other as if kissing, the black interval between them being entirely obliterated. They then appear to spring suddenly apart. If we take a white cardboard hand and view it in the same way it is almost impossible not to think that we are viewing a living

hand: the thumb moves towards the fingers, the fingers move together and various portions of the hand disappear and reappear. It will be found that the appearance and disappearance correspond with the intermittent flow of visual purple from the periphery to the central region. It is easy to devise numerous other experiments of a similar nature.*

It is easy to show in many ways the influence of stimulation of the periphery of the retina upon the central vision. Systems of lighting in which there is a bright central area and dark surroundings are most uncomfortable. In a card room, for instance, if the tables be only lighted by a shaded light over each table some are sure to complain and suffer from headaches; this is entirely removed when a large central light is used as well, thus giving rise to peripheral stimulation. Apart from the discomfort when the surroundings are very dark and the centre very light, there may be great difficulty in seeing at all. This can be noted in the lighting of some cinematographs. Not only do a great many suffer from headaches, but to many the pictures appear blurred and indistinct.

In certain cases of diseases of the eye some portions of the periphery supplying visual purple are destroyed, and on examination it will be found that whilst with both eyes the visual acuity is normal in ordinary daylight and remains normal for the healthy eye when the light is diminished, it will drop considerably for the affected eye, the central visual acuity being, for instance, only a third of the other eye.

If we look at two small isolated stars of equal magnitude, either may be made to disappear by looking fixedly at it, whilst the other remains conspicuously visible. The phenomenon is most marked on a dark night, and when the star looked at is in a portion of the sky comparatively free from other stars, and when only one eye is used. On a very dark night a considerable number of small stars, occupying the centre of the field of vision, may be made to disappear, whilst stars occupying other areas of the field of vision are plainly visible.

Other lights or objects, when small and with dark surroundings as, for instance, a piece of white cardboard on black velvet, may be made to disappear in a similar manner.

No change can be observed if a very bright light, a group of stars, or a uniformly illuminated surface be made the subject of the experiment.

If in a dimly lighted room a piece of black velvet about three feet square be fastened upon a door and in the centre of the velvet a pin be inserted so that the head faces the observer, the head of the pin is a conspicuous object surrounded by the black velvet. It if be looked at fixedly with one eye it will disappear, and after a few seconds the whole of the black velvet and door will disappear, and the visual field becomes considerably contracted, the wall-paper on either side of the door appearing to unite.

The Effect of a Stimulus of Short Duration.

If a bright object be rapidly moved in an absolutely dark room or if a bright object be shown for a fraction of a second, six definite stages will be seen before the visual field resumes its normal appearance.

(1) The primary image.
(2) A dark interval.
(3) The secondary image.
(4) A second dark interval.
(5) A tertiary image.
(6) A dark phase which lasts until the visual field resumes its normal appearance.

The secondary image has been the subject of much discussion. It was first observed by Purkinje. It appears in an interval of about one-sixth to a quarter of a second after the commencement of the primary image. Von Kries has stated that the secondary image is not to be found with the fovea. But this appears to be due to his method of experimentation, as a retardation of the image would produce exactly the same effect. Hess points out that in the foveal region the secondary image is bent outwards.

I quite agree with Hess that the secondary image can be seen with the fovea, and this can be demonstrated easily in the following way:—If a strip of white paper be moved backwards and forwards over a dark background in a dimly lighted room, it will be noticed that after a dark interval the piece of white paper is followed by the secondary image, which becomes bent outwards when the central portion of the field of vision is reached. Hess also finds that the secondary image is seen with red light.

* See the "Physiology of Vision," G. Bell & Sons, London, 1920.

The following method shows still more conclusively how the recurrent image can be seen in the foveal region. A series of small electric lights should be arranged in a straight line in a dimly lighted room and the observer be situated at such a distance that the images of the centre light fall upon the foveal regions of his retina. On closing one eye and covering that eye with the hand the centre light is carefully observed, whilst another person turns out all the lights simultaneously; these are allowed to be visible for about a second. Four definite stages will be noticed, that is to say, (1) Continuation of the sensation. (2) Period of darkness. (3) The recurrent image. (4) Period of darkness (negative after-image), in which the details of the objects, such as the outline of the filament, can be noticed. In the second stage both the light and the dark parts of the object appear dark and no details are observable. It will be seen that the recurrent image is more marked with the foveal region than anywhere else, in fact, it might be missed in any other part. The above phenomenon can be seen very easily with the electric advertising signs which are so common and in which a number of illuminated letters appear and disappear at short intervals.

The fourth stage lasts longer than the third and the fifth much longer still. Hess gives fifteen seconds as the duration of the six stages, the last ten seconds are occupied by the sixth stage.

The curving of the secondary image can be explained by a retardation of the sensation in the foveal region, because the visual purple has to flow into this region from the periphery. Hess lays particular stress upon the fact that the phases, especially the three bright and three dark phases, are similar for the region in which there are only cones to that in which rods are found.

Purkinje Phenomenon.

Purkinje stated that if a red and blue of equal intensity be diminished in the same proportion, the blue appears much brighter than the red.

The Purkinje phenomenon is a photo-chemical phenomenon, and is found with other photo-chemical substances.

Purkinje Phenomenon in the Centre of the Field of Vision.

A hole of about 2 cms. (in diameter) is made in a door between two dark rooms; the hole is filled with two glasses, one red and one blue, placed one above the other so that half is red and half blue, the red being decidedly in ordinary conditions the brighter of the two; a lamp with an obscured glass moveable on a bench is arranged immediately behind the two glasses. When the lamp is close to the glasses the red is decidedly brighter than the blue in all positions of the eye. When the lamp is moved a certain distance away from the glasses, it will be noticed that, whilst the red is the brighter of the two when the image falls on the fovea, on moving the eye so that the image falls peripherally the red is seen very dark or black and the blue is seen as a bright white light. On moving the lamp still further away it will be noticed that the blue will be seen the brighter of the two even with the fovea. This experiment reconciles the statements of those who declare that the Purkinje phenomenon is to be found in the fovea with those who declare that it is to be found in the periphery and not in the fovea; results depend on the intensity of the light employed.

An even better experiment may be made with spectral colours which can be diminished in the same ratio. Quantitative measurements can then be made. The result is the same.

Effect of Moving Material on Centre of Retina.

On opening one eye on awaking in the morning and looking at the ceiling the central portion is seen as an irregular, circular, rhomboidal or star shaped black spot. On closing the eye again a bluish violet circle appears at the periphery or middle of the field of vision, contracts, and then after breaking up into a star-shaped figure and becoming brighter, disappears, to be followed by another contracting circle. If the eye be opened when the star figure is formed in the centre it will appear as a bright rose coloured star, much brighter than any other part of the field of vision. If, however, we wait till the star has broken up and disappeared before opening the eye, it will be found that only a black spot is seen in the centre.

Time of Interval Between Contracting Circles.

I have timed the contracting circles with a stop-watch and find that the interval between two is very irregular. They may

follow each other regularly at intervals of one or two seconds and then cease. They are not apparently synchronous with the pulse or respiration, and they still go on moving when the breath is held.

Let us consider the theory that supposes that the rods are percipient elements for perception in a dim light, whilst the cones are the percipient elements in daylight. This theory is a very irrational one, for it is difficult to conceive an element stimulated by the decomposition of a photochemical substance which is excited by a weak light and not more strongly by a brighter light. What is the supposed function of the rods during the daytime? Apart from the numerous facts against this theory, it will be found that it is supported almost entirely by misstatements, namely (1) That certain animals have only cones, and others have only rods; (2) That the periphery of the retina is colour-blind; (3) That the eye is totally colour-blind in dark adaptation; (4) That the Purkinje phenomenon and the recurrent image are not found with the fovea.

(1) Though I have examined numerous collections, I have never been able to find any animal with only rods or only cones, neither have I found anyone who has seen such a retina. The tortoise is the most quoted; it is stated to have only cones. The rods and cones in the retina of the tortoise are as clearly defined and distinct as in the human retina. (2) The periphery of the retina is not colour blind when colours of sufficient intensity are used. The reader can test this for himself with a doctor's red lamp. He will find he can see it as red to the extreme periphery. (3) In dark adaptation the eye is not totally colour blind. Those interested in the subject should read the masterly paper by Burch on "Colour Vision by Very Weak Light." Proceedings Royal Society Vol. 763, page 199.

Lately, Professor Andrade and I have found that the colour of the yellow spot may be demonstrated by weak light. If three white discs, each about two inches in diameter, be fastened on a black ground in a dimly lighted room, in a line with an interval of two inches between them, on viewing them so that the centre one falls on the yellow spot, this appears darker and orange-yellow, whilst the two others appear bright bluish white. There is no scotoma corresponding to the rod free portion of the macula which is equal to a visual angle of about 3°. (4) The Purkinje phenomenon and recurrent image are found with the fovea.

It is difficult to comprehend how vision can take place on the theory. How are the central connections in the brain arranged in order to obtain localization, especially with a large scotoma in the most important part of the field of vision? It has been shown that this scotoma only exists in certain circumstances. As a small red light is quite visible on a dark night, and this is seen with the fovea, calculation will show the very small amount of light falling upon the eye, and by which it is visible.

DISCUSSION.

The Chairman said the power and nature of vision was a subject which affected and interested everyone to such an extent that, no matter what our experience might be, we always felt ourselves justified in criticising, or even forming, theories with regard to it. Men engaged in the most diverse branches of knowledge had invented theories of vision and brought forward facts in support of their hypotheses. One of the earliest authorities on colour vision was Goethe. Dalton, the chemist, and many physicists had taken the matter up; and the theory of Young, as modified by Helmholtz, might be considered the orthodox doctrine on the subject.

Possibly on account of the general interest taken in the matter, the theories brought forward with great authority by men of the intellectual magnitude of Young, Helmholtz and von Kries possessed, as it were, too much inertia; they had too much authority behind them. It was of the utmost importance to divest such theories of the authority of the men who gave them birth, and regard the facts *de novo*, in order to see whether they really supported the theories based upon them. It was a great advantage, therefore, that a man like the author, who had devoted a lifetime to the subject, should examine them from the physiological standpoint, and that the orthodox theories should be scrutinised in the light of physiological facts. By "physiological facts" he meant those which one could observe, sometimes on animals, but more often on oneself.

The author had confined himself almost entirely that evening to the fundamental question of why we see at all. In order to be aware of what was happening in the world around us, we were provided with sense organs—machines which would detect movement around us and carry the information to the brain. There were things in our tongue which told us about the movement of molecules, the chemical nature of the substances we took into

our mouth; there were machines called ears, which reacted to vibrations of a certain frequency in the air around us, and in our eyes we had other machines which picked up different and much finer vibrations; we called the sensations they aroused light.

Examination revealed that in all the sense organs there were two kinds of cells. In the case of the organs of hearing, taste and smell, one variety of cell was spoken of as the sensory cell, and the other was regarded as helping it in some way not as yet understood, and was known as the accessory cell. In the retina, those two kinds of cells were known as rods and cones, and there could be no question but that the cones were the most important sensory cell, because in the centre of the retina, which was the region of most distinct vision, there were only cones.

The question then arose as to what was the function of the rods. According to the orthodox theory put forward by von Kries, and very generally accepted, the rods were also sensory cells, and, whereas the cones were used in daytime for the appreciation of colour, the rods were used at night, when the light was so dim that colour could not be appreciated: their vision was supposed to be colourless. That was known as the duplex theory.

The author disagreed with that view, and held that there was no evidence that the rods were sensory; he maintained they were accessory, and were the sensitisers of the cones, and that they secreted a substance which had long been known to be changed by light. He said that that substance was a necessity for any understanding of the functioning of the cones, for, if the orthodox theory were accepted, some invisible substance similar to visual purple had to be postulated for the cones, which would be affected by light, whereas the visual purple had been recognised for forty years, was known to be affected by light, and might, therefore, be the sensitiser and the actual stimulator of the cones. That was the author's theory, and he had brought forward a number of cogent arguments in support of it, arguments which members of the audience who were more acquainted with the subject than he personally was could criticise. The author's theory, however, was consistent with known physiological facts, and, therefore, worthy of thorough investigation.

Professor E. N. de C. Andrade said the subject of vision, on which the author had done so much pioneer work, was a very fascinating one, the more so because it embraced many problems as yet unsolved by physiologists, but in regard to which any one could carry out simple experiments for himself. For example, on awakening one morning he saw the whole of the hexagonal pigment figures of the retina on the ceiling, and they stayed there for some time. Physiologists admitted that one could sometimes see those figures, but were ignorant of the conditions under which one could be sure of seeing them. If one looked at a very bright light for fifteen seconds and shut one's eyes, a red figure would appear and die away a number of times. Exactly what governed the number of times it appeared and the interval between them was unknown. Anyone could make experiments with lights of various intensities, counting the number of appearances and the intervals between them. When watching a cart in motion the spokes of the wheels sometimes appeared to be stationary and fixed. He had discovered the cause of that illusion, but to make the matter more interesting he would not mention it. It was not one of the accepted explanations. The physical side of the problem could be summed up by saying that we see a lot of things that are not there and do not see a lot of things that are. To the psychologist that did not matter at all; it only made his science more interesting. To the spiritualist it was meat and drink; but to the physicist, who was less poetically inclined, it was a serious matter. It went to the root of all he did and made his work very difficult. If, for instance, one placed a dark square on a lighter card, one could see round the square a darker line, but in reality there was no darker line there at all. Instead of relying on the eye, physicists had been obliged to have recourse to complicated electrical devices for measuring the position and nature of spectral lines as recorded on a photographic plate. It might be that the famous canals of Mars only existed in the retina, because if one drew a picture of Mars and put a number of splotches on it and walked further and further away from it, before one lost sight of the splotches altogether they appeared to be connected up by lines.

There was a psychological aspect to the subject which the author had not touched upon. On going into a dark room illuminated with red light everything at first seemed pink, but in time the various objects assumed their proper colours. In all probability that was not physiological but psychological; one knew perfectly well that the objects were not pink, and so, after a time, one's reason predominated and one saw them in their natural colours.

The author had shown certain experiments which he himself had devised, but for their success certain conditions were essential; the light must be faint and come from behind the spectator. It might be they would work better in a red light; he had not tried it yet, but had noticed that at seances, where things were said to be seen moving about, there was usually a red light. He once had occasion to review a book on hypnotism, in which the writer said that the hypnotic fluid must actually exist because it could be seen. He pointed out that that was a bad argument. The

writer went on to remark that once when making magnetic passes with a faint light behind him he had seen the fluid coming from his fingers. Personally he had obtained the same result from a cardboard hand.

Mr. Edgar Jepson, referring to the statement in the paper that when the periphery was fully illuminated one obtained much clearer vision, asked how that acted in the case of animals which saw in the dark. The cat could see quite as well in the day time with its periphery fully illuminated as in the dark; but as soon as the owl came into daylight it obviously saw very badly indeed, though its periphery must be more fully illuminated than at night. In the case of human beings what was known as dark adaptation occurred; if one looked at a spectrum in the dark it was white, but after a time the colours returned. If an owl was out in the light long enough, did a light adaptation occur? Could the owl eventually see quite well—as well as it did in the dark?

Mr. Leon Gaster said the author had been very courageous in setting forth his views, which he had defended for many years. The subject of glare, especially in relation to the after image, was of great interest; possibly the author could say what would be the degree of brightness which one could look at without danger. The last Departmental Committee of the Home Office had made certain recommendations with regard to cutting off the glare at certain angles, and further information on the subject would be of interest. There was at present no generally acceptable physiological test of what was or was not a glaring source.

The same question arose in regard to the headlights of motor cars; it was very difficult to determine when a light became dangerously glaring. When it was so strong that one had to put one's hand in front of one's eyes, that was obviously intolerable; but some better and more scientific definition was required. Certain recommendations, made in the interests of public morals and safety, had been made with regard to the lighting of cinematograph halls, and it was interesting to learn from the author that those recommendations were justified from the physiological point of view also, since in halls with no side lighting the contrast between the brightness of screen and surroundings was too great for comfortable vision.

Mr. R. H. Parsons asked for information on certain points which might be clear to physiologists, but which presented difficulties to ordinary physicists. The theory of the lecturer apparently was that sight was due to the stimulation of the cones by a chemical substance formed in the visual purple by the action of light. If the visual purple were regarded as being chemically sensitive to light, so that light affected it permanently as in the case of a photographic plate, vision should cease after a short exposure when the chemical change was complete. This, however, was not so, as one could see an object so long as the eyes were directed towards it. It would be interesting to hear the author's views as to what chemical or other change did occur in the sensitive fluid. He spoke of the latter as something renewed by the rods. If, however, the change were of the nature of a molecular or structural strain, this would be relieved when the light ceased and there would be no reason for renewal of the fluid. If, on the other hand, the change were permanent, and the fluid had to flow back to the rods to be resensitised while sight was going on, it was difficult to see how any sharply defined stimulus was possible to the cones which were being washed by currents of spent and unspent fluid. Furthermore, if the visual purple were being formed all the time by light, what light was it that was doing the work? The only light coming into the eye was that which fell on the retina in the form of a picture, and as the whole of this light was necessary for seeing the picture the speaker did not understand what light was available for re-sensitising the fluid.

Mr. Frederick G. Hawkes, referring to an experiment demonstrated by the author for showing the sensitiveness of the periphery of the retina to coloured light, suggested that it should, to be conclusive, be carried out in a very dark room, which did not contain any object which could reflect the light. Otherwise, he thought, the fovea could receive the red light by reflection from surrounding objects. He would, therefore, like to know how the experiments were originally carried out.

Mr. J. S. Dow said his acquaintance with the author's work went back twenty years, to a time when he was reading a paper on photometry and endeavoured to explain his facts by a theory current at the time, which ascribed a light-percipient quality to the rods as well as the cones—a theory which was, he believed, quoted quite frequently in text books even at the present time. The author's contribution to the discussion on that occasion was in the nature of a bombshell, but he was able to show that the facts he himself had adduced could be explained by his theory, which was, perhaps, a good thing for the facts. There had been many other subsequent photometric experiments on which the author's theory of what took place at low illuminations had an important bearing. It was rather surprising that so many of these simple experiments which could be made at low illuminations were not generally known. If one put one's hand

together in a very feeble light and then drew them apart, a distinct after image could be distinguished. He had seen that referred to in books on psychic subjects as evidence of some mysterious current of force. It was not appreciated that it was merely an optical illusion. The question of after-images was very important in connection with glare. After-images were very complex, but it should be possible to get some indication of the extent of glare by the duration and severity. The data at present available were almost entirely qualitative. He had seen little work in which the duration of the after-image and the brightness or length of exposure were connected. In some recent experiments on the conditions in mines, the author did make use of that very test, and found that with the filament exposed the number of after-images and the duration for which they persisted was greater than when the lamp was screened. That was a matter which physiologists should study closely, because it had practical bearings of considerable importance.

The author referred to the well-known fact that a star could often be seen by oblique vision when not otherwise visible. Possibly he might be able to throw some light on the impression often utilised in novels, that by going to the bottom of a coal mine and looking upwards one could see the stars. Personally, he could not conceive any physical reason why that should be the case; the mere fact of the blackness around would not alter the contrast between the stars and the sky.

Captain Colin Nicholson, R.N.R. (Mercantile Marine Service Association) assured Mr. Dow that with the naked eye it was possible to see the planets, or at any rate Venus, by daylight. Venus could be seen quite easily in broad daylight from the deck of a ship. He had seen it scores of times in the brightest sunshine. It was quite easy to find it by means of the sextant, or, with practice, when one knew where it was, by simply looking up. He had often got passengers to stand underneath a cringle in the awning, and, using that as a guide, pointed it out to them, and they always saw it, or said they did; he could not be certain whether they really did.

The Author, in reply, having thanked the Chairman for his kind remarks and for presiding, referred to Mr. Jepson's question with regard to the owl, and said that obviously an animal or bird whose eyes contained an enormous preponderance of rods was well fitted for seeing in the dark. In the case of a cat, for example, during ordinary daylight its pupil contracted to the finest slit, while in the dark the pupil was widely dilated, allowing in every possible ray of light and producing peripheral stimulation. The owl behaved in daylight exactly like a man who had been shut up in a dark cellar, and whose visual purple had consequently accumulated to such an extent that there was an excess, and the decomposition of that caused the sensation of glare.

Glare was largely a matter of the actual contrasts in the field of vision. For instance, in Egypt the whole eye was flooded with light which, if it only went on a small portion of it, would produce glare. A small light in a dark room was intensely disagreeable. That applied to cinematograph theatres; he had noticed many years ago that those in which the surroundings were absolutely dark, no matter how suitable they might be for loving couples, were all closed down in a few months, whereas those well lighted at the sides remained. When mentioning the matter a few weeks ago, he was told by a member of his audience who was rather short-sighted that he had observed the same effect; in a hall which was very dark at the back, the pictures seemed blurred and indistinct; and on complaining to the manager he was told he was the twelfth man to make the same complaint in the last five minutes. The question had been taken up in America, where exact measurements were being made of the amount of peripheral stimulation necessary. It was the same with the amount of light needed for the regeneration of the visual purple; if one put a rabbit's eye in the sunlight it would be completely bleached; one had to judge the amount of light with which the regeneration of the visual purple would be quicker in light than in darkness.

Time would not permit him to deal with all the comments that had been made, but he might mention that the pigment cells threw out processes in daylight, and that would isolate and obstruct the flow of the visual purple. The flow of the visual purple seemed to be steady from the periphery to the centre. There was a simple experiment in that connection which anyone could make for himself. If one's bedroom contained two windows with a portion of wall between them, and on waking in the morning one looked at those and then shut one's eyes, one would see the two windows, but the portion of wall would be quite blank. If one then put one's head under the bedclothes and shook it from side to side, it would be found that the whole of the white part spread out, and there was no blank part at all; simply a sort of oval. It was not likely that the film itself was shaken, but it was squeezed by the muscles of the eye. The whole subject of glare in lighting required thorough examination and investigation.

In reply to Mr. Hawkes, the sensitiveness of the periphery of the retina to coloured light was demonstrated by throwing a small beam of light of a spectral colour. The observer looked at a fixed spot, while the light was moved. First of all, one could tell how bright it had

to be for him to be able to see the colour, and by diminishing the light a point was reached when he could not see the colour, but could match a grey.

On the motion of the CHAIRMAN, a hearty vote of thanks was accorded to the author for his paper.

The proceedings then terminated.

NOTES ON BOOKS

INTERNATIONAL ATLAS OF THE WORLD. New York and Chicago; Rand, McNally and Co.

Messrs. Rand, McNally and Company are to be congratulated on the production of this very handsome volume. It contains large scale coloured maps of each state, territory, and outlying possession of the United States, the provinces of Canada, and every country in the world. Most of these maps are admirable, but if we were to suggest a criticism it would be that some of them, notably that of Pennsylvania, are so crowded with detail that it is difficult to see the wood for the trees. There is, however, a very fine index which contains the names of something like 40,000 towns in the United States, with their populations, and by its aid it should be possible to find any place of which one is in search.

Each map is accompanied by a page of letterpress giving the area, populations, resources, industries, climate, etc., of each state or country; and many of these articles are enriched by coloured illustrations. An Englishman—or even a Scot—may possibly think that his country deserves more space than is devoted to, say, Saskatchewan, but no doubt there are reasons which render it necessary to preserve uniformity in this regard. The letterpress is exceedingly well done, the amount of information contained being extraordinary; and any one who studies this atlas carefully will have a good idea not only of the size and shape of the world, but of its principal institutions, trade and resources.

THE POCKET GUIDE TO THE WEST INDIES.—By Algernon Aspinall, C.M.G. London: Sifton, Praed and Co., Ltd.

A fourth edition of this excellent handbook is very welcome. The third edition appeared in 1914, since when several important events have taken place in the Caribbean area, the most notable being the opening of the Panama Canal and the transfer of the islands of St. Thomas, St. Croix, and St. John from the Dannebrog to the Stars and Stripes in 1916. A very good account is given of the Panama Canal, with a map and an illustration of H.M.S. Renown passing through the Culebra Cut in 1920.

The book is crammed with information likely to be useful to the tourist, not only when he reaches the West Indies, but also on the voyage out. Thus a good bibliography is given of books dealing with all sorts of aspects of the West Indies, while useful hints about such matters as Customs, postal services, etc., are not forgotten. The descriptions of the various islands and districts are very good. Of the many interesting and beautiful sights to be seen in the West Indies none can be nore remarkable than the Kaieteur Fall in the Hinterland of British Guiana. Here the river Potaro, a tributary of the Essequibo, flows over a sandstone and conglomerate tableland into a deep valley below, with a total fall of 822 feet, or five times the height of Niagara. "For the first 740 feet the water falls as a perpendicular column into a basin below, from which it continues its downward course over a sloping cataract 81 feet in height, and through the interstices of great blocks of rock, to the river below. The width varies from 350 feet in the dry season to 400 feet in the rainy season, and the depth similarly varies from a very few to 20 feet."

OBITUARY.

SIR NARAYAN GANESH CHANDAVARKAR, B.A., LL.B.—The death from heart failure on May 14th of Sir Narayan G. Chandavarkar, the able, enlightened and much respected President of the Bombay Legislature, is announced from India. Born in 1855 he studied at the Elphinstone College in Bombay under Principal William Wordsworth, who was described by Sir W. W. Hunter as "one of the most distinguished public teachers who ever laboured in India," and who exercised really remarkable influence on educated Indians of his day. After completing his University education young Chandavarkar became a Pleader of the Bombay High Court and also for a time was English editor of the *Indu Prakash*, a well conducted bilingual journal. A pioneer of the National Congress he presided at one of its earlier sittings, but he always seemed to be chiefly interested in educational progress and social reform; for example, he applied himself with characteristic courage to the advocacy of a Bill introduced during Lord Lansdowne's Viceroyalty to raise the age of consent and for many years he was the devoted General Secretary and mainstay of the National Social Conferences. From 1909 to 1912 he was Vice-Chancellor of the University of Bombay. He had previously been raised to the Bench of the local High Court and on more than one occasion was chosen to act as Chief Justice. On retiring from the Judiciary he served in Indore for a few months as Chief Minister to the Maharaja Holkar. Later Sir Narayan was instrumental in settling certain labour disputes and among his activities was the Chair-

manship of the Bombay Elementary Education Committee. He was the successor of the late Mr. Justice Ranade as President of the Prarthana Samaj of Bombay, a theistic society founded about sixty years ago. He was knighted in 1910. Sir Narayan Chandavarkar had been a Fellow of the Royal Society of Arts since 1915.

HIGHWAY CONSTRUCTION IN SZECHWAN.

The good-roads movement is being felt in Central China, and an American engineer has recently been engaged to supervise the survey of a proposed motor road from Chungking (which is nearly 1,500 miles up the Yangtze River from Shanghai) to Chengtu, the capital of the Province. The entire province of Szechwan is a very fertile and productive valley, surrounded by mountains with altitudes ranging around 10,000 feet, and hitherto the population of this province (estimated at 76,000,000) has had almost no transportation facilities.

For a great many years, writes the United States Vice-Consul at Chungking, efforts have been made to arrange for railways to penetrate this district and for highways to open up the Province. Last year it was reported that the provincial government were considering the construction of approximately 2,000 miles of modern highways. It would appear, therefore, that the making of the above mentioned survey represents definite progress, and it is to be hoped that the construction of the Chungking-Chengtu road, which would be over 200 miles in length, is a definite step in the direction of making these dreams a reality.

The construction of a motor road between the above cities will have a most pronounced effect upon the life of the entire Province, as up to now the conditions have been such as to make it impossible to use wheeled vehicles in this region. Even jinrikishas and Chinese wheelbarrows are little used because of the absence of roads. The only transportation available is by boat or coolie bearers, and both of these methods are slow, expensive and unsafe.

The wonderful natural resources of the Province of Szechwan and its large population of hard-working, intelligent Chinese will have a tremendous influence on the Trade of China as soon as the region can be brought into contact with the trade routes of the world.

PRODUCTION OF GUMS IN THE RED SEA DISTRICT.

The three principal gums produced in the Red Sea district are, in order of importance, gum myrrh from Abyssinia and the hinterland of Arabia; gum arabic or luban, from Somaliland and Mokalla; and gum frankincense, from British Somaliland, the independent Somali ports, the Yemen of Arabia, and the island of Socotra. Of the gum myrrh, that from Abyssinia is considered the best. Except in the case of gums from the interior of Arabia nearly all the importers are Somalis from the wild hinterland of Africa, who bring their goods with them in the crude uncleaned state for sale to Indian merchants in Aden, where they are cleaned and prepared for the export trade. According to a report by the United States Consul at Aden, the arrivals of these gums last year were good, except from the hinterland of Arabia, where internal troubles greatly interfered with the gathering of gum.

The following table shows the exports of these gums during the years 1920 and 1921. Practically all of these exports were shipped from the Port of Aden :—

Quantity and value of gums exported from the Red Sea District in 1920 *and* 1921.

Countries of destination.	1920. Hundred-weight.	1920. Value.	1921. Hundred-weight.	1921. Value.
		£		£
Gum myrrh :				
Egypt ...	6,575	15,539	6,633	15,134
India (Bombay)	11,094	17,069	1,884	5,372
United States ..	341	2,569	261	2,030
Other countries	3,141	7,367	2,794	8,140
Total ...	21,151	42,544	11,572	30,676
Gum arabic :				
United Kingdom	283	1,063	1,058	1,722
India (Bombay)	9,227	19,338	3,208	5,927
France ...	---	—	234	513
Other countries	670	2,272	935	1,149
Total ...	10,180	22,673	5,435	9,311
Gum frankincense :				
United Kingdom	628	907	1,068	3,180
India (Bombay)	7,746	12,239	2,619	3,018
Egypt ...	8,183	15,148	1,891	3,458
France ...	5,085	14,937	845	1,425
Abyssinia ..	3,359	4,814	5,164	6,189
Other countries	3,808	5,099	3,735	4,972
Total ...	28,809	53,144	15,322	22,242

MERCURY ORES.

A new volume on Mercury Ores, in the Series of Monographs on Mineral Resources, with special reference to the British Empire, issued under the direction of the Mineral Resources Committee of the Imperial Institute, has just been published by Mr. John Murray (price 5s). It is written by Mr. Edward Halse, A.R.S.M., M.Inst.M.M., Scientific and Technical Department, Imperial Institute.

Mercury or quicksilver, although somewhat widely distributed, only occurs in economic quantities in a few deposits in the world. It is largely used in the manufacture of certain drugs and chemicals. In the earlier part of the war fulminate of mercury was in great demand for detonating high explosives, but, later its use in this respect was largely superseded by other chemicals. The metal is also used in the manufacture of vermilion, and of red oxide of mercury, utilised in preservative paints for the bottoms of ships. Mercury is also used in certain electrical apparatus, in the construction of certain instruments, in the amalgamation of gold and silver ores, and for a few other purposes. The world's annual production of mercury in pre-war years amounted to about 4,500 short tons. During the war, 1917 was the only year in which the production exceeded this amount by about 160 tons, which was largely due to the increased outputs from the United States and China. Since the war, there has been a sharp decline in the world's production, that for 1921 amounting to about 2,332 short tons, or nearly half of the 1912 production. This fall in production has been largely due to the suspension of working of many of the low-grade mines of the United States, and to a decrease in the exports from China.

The first chapter of the monograph deals briefly with mercury minerals; the mining methods, concentration and reduction of the same; and the properties, uses, prices and world production of the metal.

In the second chapter the deposits of the British Empire are described, the principal being those of Kamloops Lake and Barclay Sound, Vancouver Island, British Columbia; Pulganbar, New South Wales; Kilkivan and Cooktown, Queensland; Puhipuhi and Ohaeawai, New Zealand.

The third and last chapter describes the mercury deposits of foreign countries, notably those of Idria, in Carniola; Monte Amiata, in Italy; Nikitovka in Southern Russia; Almaden in Spain; the United States and Huancavelica in Peru. The minor occurrences of Yugo-Slavia, Asia Minor, China, Mexico, Brazil, Columbia, and other South American countries are also described.

A map shows the chief mercury occurrences in the world, and the volume concludes with a list of publications on mercury.

THE BELGIUM LACE INDUSTRY.

The lace industry has existed in Belgium for over 400 years, during which time it has passed through various phases of prosperity. At present the manufacture of handmade lace is at a low level, the number of lace makers in Belgium having shown a steady decrease since 1870, when there were, according to most authorities, about 150,000 in the country. There now remain only about 30,000 lace makers in Belgium, in contrast with 45,000 before the war. This decrease of 15,000 workers has occurred, especially since the armistice, owing to the extensive employment of female labour in factories during the past few years.

According to a report by the Secretary to the United States Trade Commissioner at Brussels, lace making, centralised chiefly in East and West Flanders, is essentially a home industry, especially adaptable to an agricultural country, where the attraction of more remunerative work in industrial centres does not influence the labour supply. Lace workers rarely work the year round at this occupation, but employ an important part of their time in agricultural or other labour. For an average worker, from 100 to 150 days in the year are given over to lace making.

About half of the lace makers in Belgium are found in West Flanders and about two-fifths in East Flanders, both regions eminently agricultural in character. A few lace makers are scattered through the other Provinces, except Liège, where no lace is made. Some of the important lace-making centres in West Flanders are Thielt, Bruges, Dixmude, and Roulers, and in East Flanders, Alost and Termonde. The industry exists in a smaller degree around other centres in these Provinces, but shows a tendency to disappear entirely in the north of East Flanders, where industries centred in small towns attract female labour. Cigar factories, glove making, lingerie, and various other small industries have taken a good number of lace makers away from their original occupations. In these and other industries female labour often receives 6, 8, and even 10 francs for a day's work of eight hours, whereas only good lace makers can at present earn 4 francs a day. Numerous convents and lay schools give instruction in lace making and turn out many skilful workers, but these workers leave the lace industry for more remunerative labour when they approach the age of 18 years.

A serious source of competition for Belgian hand-made lace is imported machine-made lace from Germany, France, and England. German competition in torchon and Cluny laces is most serious, as these two kinds are especially adapted to machine-made imitations. French and English machine lace imitates the finer laces, such as Valenciennes, and offers excellent imitations, but Belgian manufacturers

of the hand-made article state that these imitations do not equal the better quality of real lace. All bobbin-made lace is more or less successfully imitated, but needle-made lace (Brussels, Venice, rose, etc.) has not yet been especially well imitated. It is evident that the prosperity of the handmade industry depends greatly on the production of the finer laces that cannot be well imitated by the machine-made article, and it is precisely for these laces that the supply of labour is the least.

Estimates of the production of lace in Belgium are extremely varied, but a conservative and probably accurate estimate of the pre-war annual production is 15,000,000 francs' worth of lace of all kinds. The quantity of lace produced at present is only about half the pre-war production, but values having more than trebled it can safely be said that the annual production is now in the neighbourhood of 25,000,000 francs. Of the total production, about 25 per cent is Cluny and torchon, 25 per cent. Valenciennes, and 15 per cent. Venice. Brussels, Bruges, and Milan (or Flanders) laces form a large portion of the remainder of the production. Chantilly is practically no longer made in Belgium. Owing to the fact that the value of lace varies greatly over short periods, and depends upon the workmanship of each piece, price estimates are misleading.

Machine-made lace has not been extensively produced in Belgium, but this industry has shown a certain extension since the war. Befo e the war there were two establishments producing machine-made lace, with an annual production valued at 700,000 or 800,000 francs. The personnel employed was something over 100 persons. At present there are three such establishments in the country, employing about 300 workmen and producing about 2,500,000 francs' worth of lace annually.

CULTIVATION OF OPIUM POPPY IN EGYPT.

Opium poppy, which has been cultivated in Egypt from a very early date, is grown for the narcotic alkaloid opium which it contains. According to a report by the United States Consul at Alexandria, the locality most favourable to its growth, and where it is most extensively cultivated, is Kena Province, 75 per cent .of which is under opium poppy.

Prior to 1914 a considerable amount of opium was imported, mostly from Smyrna, but its quality is inferior to the Egyptian variety. With the outbreak of the war importations ceased and the demand for Egyptian opium increased. In 1918, however, the Government issued a decree prohibiting its cultivation in order to increase the area under cereals. This caused the price of opium to advance tremendously. It is said to have reached about £20 per pound in the Province of Kena during the summer of 1920.

Harvesting of opium takes place about the middle of March. Fresh opium is sold to merchants at the rate of 14 Egyptian ounces to the rottle (1 rottle = 12 English ounces). The merchants shape it into round discs, each weighing from two to three drams. These discs are brushed with the white of egg to present a better appearance. Dry pure opium is black red, resembling cooked coffee. On breaking it shows a soft compact fracture. It is often adulterated with lentil flour or mixed with "mor higasi," a gum from Hedjaz. Cooked and ground helba or coffee and the epidermis of the pericarp are other adulterations used, but these adulterations can be detected. Pure opium burns without leaving a residue and contains not less than 10 per cent. of morphine—sometimes as much as 12 per cent. Oil extracted from the seed (50 to 60 per cent.) is used in painting.

The Egyptian Government controls the cultivation of opium, since it was being sold for native consumption in considerable quantities and with bad effect.

GENERAL NOTES.

Mesopotamia.—A loan collection of pictures painted by Miss Edith Cheesman in Mesopotamia is now on view in the North Gallery of the Imperial Institute from 10 a.m. to 5 p.m. daily, except Sundays. Admission free. The pictures which are in oils and water colours are illustrative of life and scenery in Mesopotamia and include both portraits and landscapes.

Production of Citrus Fruits in Greece.—The 1922 crop of citrus fruits in Greece shows a marked increase over that of 1921. According to figures furnished by the United States Vice-Consul at Athens, the number of oranges picked was 152,000,000, compared with 53,000,000 in 1921; mandarins, 63,000,000 compared with 18,000,000 in 1921; and lemons 49,000,000 compared with 31,000,000 in 1921. The total production of all citrus fruits amounted to 264,000,000 pieces compared with 102,000,000 in 1921, an increase of 159 per cent.

New Process for Cutting Conch Shell.—A successful mechanical process for cutting conch shell has just been invented in India, according to the United States Vice-Consul at Calcutta. The new invention consists of an elastic composition grinding disc, which cuts through the shell in a manner much more satisfactory than any of the high-speed discs of various metals tried before. This invention is of considerable importance because the shell, apart from its sacred significance, forms the basis of a large and profitable industry in many centres of India, where it is cut into rings, bracelets, and other shapes.

MEETINGS OF THE SOCIETY.

ORDINARY MEETING.

WEDNESDAY, MAY 30, at 4.30 p.m.—A. J. SEWELL, "The History and Development of Children's and Invalid's Carriages." L. BERESFORD SEYLER. will preside.

DOMINIONS AND COLONIES SECTION.

TUESDAY, JUNE 5th, at 4.30 p.m.—SIR EDWARD DAVSON (President of the Associated West Indian Chambers of Commerce; Chairman of the British Empire Sugar Research Association, Vice-President of the British Empire Producers' Organisation), "The Economic Conference and Crown Colony Development." His Grace the Duke of Devonshire, K.G., G.C.M.G., G.C.V.O., P.C., Secretary of State for the Colonies, will preside.

INDIAN SECTION.

Friday afternoons.

JUNE 1, at 4.30 p.m.—AUSTIN KENDALL, I.C.S., rtd., "The Participation of India and Burma in the British Empire Exhibition, 1924." SIR CHARLES C. MCLEOD, Member, Board of the British Empire Exhibition, will preside.

JUNE 15, at 4.30 p.m.—SIR JOHN H. MARSHALL, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture.) The Most Honourable The Marquess Curzon of Kedleston, K.G., G.C.S.I., G.C.I.E., P.C., F.R.S., will preside.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, MAY 28.. University of London, University College, Gower Street, W.C., 5 p.m. Prof. G. D. Hicks, "Kant's Theory of Beauty and Sublimity." (Lecture III.)
At King's College, Strand, W.C., 5.30 p.m. Prof. R. Dyboski, "Outlines of Polish History." (Lecture V.)
At King's College for Women, 61, Campden Hill Road, W. 4.30 p.m. Prof. V. H. Mottram, "Nutrition." (Lecture VIII.)
Faraday Society, at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C., 3 p.m. General Discussion on "The Physical Chemistry of the Photographic Process," the introductory address by Prof. W. D. Bancroft, "The Theory of Photography." (2) Papers on "The Physical Chemistry of the Vehicle and of the Emulsion." 5 p.m. (1) Papers on "Reactions of the Plate during exposure (including latent image.) (2) "Papers on Development and Characteristics of the Developed Plate (including optical Properties, Sensitometry, etc.)"
8 p.m. Papers on "Adsorption Reaction in Photographic Films."
British Architects, Royal Institute of, 9, Conduit Street, W. 8 p.m. Mr. G. Scott, "Tradition and Originality in Italian Renaissance Architecture."
Architectural Association, 34, Bedford Square, W.C., 8 p.m. Lord Burnham, "Architecture and the Press."
Victoria Institute, Central Buildings, Westminster, S.W., 4.30 p.m. Rev. A. Canon A. Lukyn-Williams, "Religious Controversy between Christians and Jews of To-day."
Geographical Society, 135, New Bond Street, W., 5.30 p.m. Anniversary Meeting. (1) Presentations of Medals and Awards. (2) Presidential Address.
East India Association, Caxton Hall, Westminster, S.W., 3 p.m. Sir Patrick Fazan, "The Future of the Indian Land Revenue."

TUESDAY, MAY 29.. University of London, King's College, Strand, W.C., 5.30 p.m. Dr. H. W. Carr, "Blaise Pascal: Tercentenary of his Birth, June 19, 1923." (Lecture IV.)
Royal Institution, Albemarle Street, W., 3 p.m. Prof. Flinders Petrie, "Discoveries in Egypt." (Lecture II.)
Colonial Institute, Hotel Victoria, Northumberland Avenue, W.C., 4 p.m. Captain J. P. Tolland, "Tanganyka Territory."
Zoological Society, Regent's Park, N.W., 5.30 p.m. (1) Mr. C. T. Regan, "The Skeleton of *Lepidosteus*, with Remarks on the Origin and Evolution of the Lower Neopterygian Fishes." (2) Dr. C. F. Sonntag, "The Comparative Anatomy of Edentata, Dermoptera, and Insectivora." (3) Mr. S. Maulik, "New Cryptosome Beetles."

WEDNESDAY, MAY 30.. University of London, University College, Gower Street, W.C., 5.15 p.m. Sir Thomas H. Holland, "Phases of Indian Geology." (Lecture III.)
3 p.m. Prof. E. G. Gardner, "The Composition of the *Divina Commedia*." (Lecture III.)
6.15 p.m. Sir Joseph Stamp, "Economical and Statistical Aspects of a Capital Levy." (Lecture II.)
British Academy, at the Royal Astronomical Society, W., 5 p.m. Mr. E. Armstrong, "Italian History and Art in the Fifteenth Century."
Microscopical Society, 20, Hanover Square, W., 7 p.m. Mr. H. B. Milner, "The Microscopical Investigation of Sands for various Industrial Purposes."

THURSDAY, MAY 31.. Aeronautical Society, at the ROYAL SOCIETY OF ARTS, John Street, Adelphi, W.C., 5.30 p.m. Dr. J. S. Ames, "The Relation between Aeronautical Research and Aircraft Design." (William Wright Memorial Lecture.)
University of London, University College, Gower Street, W.C., 5.30 p.m. Prof. A. Cippico, "Ludovico Ariosto" (in Italian).
At King's College, Strand, W.C., 5.30 p.m. Dr. F. Pavlasek, "The Economic Situation in Czechoslovakia."
Royal Society, Burlington House, Piccadilly, W., 4.30 p.m.
Antiquaries Society of, Burlington House, Piccadilly, W., 8.30 p.m.
Royal Institution, Albemarle Street, W., 3 p.m. Sir W. M. Bayliss, "The Nature of Enzyme Action." (Lecture I.)
Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C., 6 p.m. Annual General Meeting.

FRIDAY, JUNE 1.. Royal Institution, Albemarle Street, W., 6 p.m. Prof. H. A. Lorentz, "The Radiation of Light."
University of London, King's College, Strand, W.C., 5.30 p.m. (Shakespeare Association). Dr. W. W. Greg, "The First Folio and the Publishers."
Philological Society, University College, Gower Street, W.C., 5.30 p.m. Dr. H. Bradley, "Dictionary Evening."

SATURDAY, JUNE 2.. Royal Institution, Albemarle Street, W.C., 3 p.m. Dr. A. W. Hill, "The Vegetation of the Andes."

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FRIDAY, JUNE 1, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

NOTICES.

NEXT WEEK.

TUESDAY, JUNE 5th, at 4.30 p.m. (Dominions and Colonies Section.) Sir EDWARD DAVSON (President of the Associated West Indian Chambers of Commerce; Chairman of the British Empire Sugar Research Association, Vice-President of the British Empire Producers' Organisation), "The Economic Conference and Crown Colony Development." His Grace the Duke of Devonshire, K.G., G.C.M.G., G.C.V.O., P.C., Secretary of State for the Colonies, will preside.

"SWINEY PRIZE."

The Council have to give notice that the next award of the Swiney prize will be in January, 1924, the eightieth anniversary of the testator's death. Dr. Swiney died in 1844, and in his will he left the sum of £5,000 Consols to the Royal Society of Arts, for the purpose of presenting a prize, on every fifth anniversary of his death, to the author of the best published work on Jurisprudence. The prize is a cup, value £100, and money to the same amount.

The award is made jointly by the Royal Society of Arts and the Royal College of Physicians. In accordance with the arrangement with the Royal College of Physicians, the award next year will be for General Jurisprudence.

Any person desiring to submit a work in competition, or to recommend any work for the consideration of the judges, should do so by letter, addressed to the Secretary of the Society, not later than November 30th, 1923.

The following is the list of the recipients:

1849. J. A. Paris, M.D., and J. Fonblanque, for their work, "Medical Jurisprudence."
1854. Leone Levi, for his work, "The Commercial Law of the World."
1859. Dr. Alfred Swayne Taylor, F.R.S., for his work, "Medical Jurisprudence."
1864. Henry Sumner Maine (afterwards K.C.B.), D.C.L., Member of the Legislative Council of India, for his work, "Ancient Law."
1869. William Augustus Guy, M.D., for his "Principles of Forensic Medicine."
1874. The Right Hon. Sir Robert Joseph Phillimore, D.C.L., for his "Commentaries on International Law."
1879. Dr. Norman Chevers, for his "Manual of Medical Jurisprudence of India."
1884. Sheldon Amos, M.A., for his work, "A Systematic View of the Science of Jurisprudence."
1889. Dr. Charles Meymott Tidy, F.C.S., for his work, "Legal Medicine."
1894. Thomas Erskine Holland, D.C.L., for his work, "The Elements of Jurisprudence."
1889. Dr. J. Dixon Mann, F.R.C.P., for his work, "Forensic Medicine and Toxicology."
1904. Sir Frederick Pollock, Bart., and Professor F. W. Maitland, for their work "The History of English Law before Edward the First."
1909. Dr. Charles Mercier, for his work, "Criminal Responsibility."
1914. John W. Salmond, K.C., for his work, "Jurisprudence."
1919. Dr. Charles Mercier, for his work, "Crime and Criminals."

PROCEEDINGS OF THE SOCIETY.

INDIAN SECTION.

FRIDAY, APRIL 6TH, 1923.

LORD MONTAGU OF BEAULIEU K.C.I.E., C.S.I., in the Chair.

THE CHAIRMAN, in introducing the reader of the paper, Mr. Geoffrey Rothe Clarke, said that gentleman had done excellent work for some time past in India, in connexion with the postal and telegraph service. He was a very "live" person, with progressive views, and probably had experienced difficulty at times in getting all the progressive reforms he desired carried out at headquarters. His paper would be

found to be of more than ordinary interest. It touched on the romance and peril of the mail runners, which had been described in verse by Rudyard Kipling, and it also dealt with problems of the future. There had been failure hitherto, though he trusted there would not be ultimate failure, to establish a postal air service between Bombay and Karachi on the one hand, and between Bombay and Calcutta on the other. The postal service between England and India was conducted, as Mr. Clarke would point out, with wonderful regularity during the War, especially when the difficulties and losses of the P. and O. were considered, but he (the Chairman) thought that the time had now come for a faster service between England and the nearest point in India. Taking the distance between London and Bombay, the average rate at which the mail proceeded was 15 miles per hour. This could not be said to be very fast in these days of improved shipping, and in the case of a service so important as that between England and the greatest branch of the Empire. Compared with the Atlantic services, of course, it was slow, but the comparison was not wholly just, because there were certain technical difficulties in the one case and not in the other. But he hoped to see some acceleration of speed. The two countries concerned were destined to work hand in hand together, and the degree in which they could do so depended, more than upon any other one factor, upon the facility and rapidity of their communications.

The paper read was:—

POSTAL AND TELEGRAPH WORK IN INDIA.

By Geoffrey Rothe Clarke, C.S.I., O.B.E., I.C.S.

Director-General, Posts and Telegraphs, India.

Previous to 1913 postal and telegraph work in India was undertaken by two separate departments, the Post Office and the Telegraph Department, and I shall give a brief account of the origin and development of each before dealing with the many problems which face the amalgamated department at the present day.

The Postal system in India, like that of other countries, had its origin in the necessity of maintaining communications throughout the various parts of a great Empire in order that the Ruler might be kept continuously informed of what was taking place and might be able to keep in constant touch with the officers in charge of provinces at a distance from the capital. When Ibn Batuta, the Arab traveller, visited India in the middle of the 14th Century, he found an organised system of couriers established throughout the country, which was governed at that time by the great Mahomed Din Tughlak. The system seems to have corresponded very closely with that maintained in the Roman Empire.

Colonel Wilks, the author of the famous history of South India, tells us that in 1672 there was a regular postal service in the Kingdom of Mysore. This service was not merely an ordinary instrument for conveying intelligence, but an extraordinary one for obtaining it. The postmasters were confidential agents of the court and the inferior servants were professed spies, who gathered all possible information from the correspondence which passed through their hands. This system, which was more fully developed by Hyder Ali, became under him a terrible instrument of despotism .

The Mogul Emperors kept a regular system of postal lines known as daks, and Ferishtah, the historian, tells us that Sher Shah during his short reign of five years, 1541-1545, was the first who ever employed a mounted post in India. The Emperor Akbar had post houses built at stages 10 miles apart on the principal roads and swift Turki horses were placed at each stage.

The British do not appear to have formed any established system of communication when they began to extend their dominions in India and in the middle of the 18th Century it was a matter of no small difficulty to send a letter more than 100 miles. A regular postal system was first introduced by Lord Clive in 1766 and the zamindars or landholders along the various routes were held responsible for the supply of runners to carry the mails. In Bengal great improvements were made by Warren Hastings; a Postmaster-General was appointed and postage was charged for the first time on private letters. At this period, 1874, the territory occupied by the East India Company consisted of three isolated areas adjoining the presidency towns of Calcutta, Madras and Bombay, each with separate postal systems. By 1827 the Indian Empire had been consolidated, and it was, therefore, necessary to consolidate the postal service. It was not, however, until 1837 that an Act was passed establishing the absolute monopoly of the East India Company in the conveyance of letters for hire. Postage was still levied according to distance; for example the cost of a letter from Calcutta to Agra was 12 annas and from Calcutta to Bombay 1 rupee, and

elaborate tables for the calculation of distances were supplied to all post offices. The Act of 1837 gave rise to much discontent, as it led to the abolition of many private postal lines which the Company was not able, at the time, to replace with lines of their own. To remedy this state of affairs, district posts were created in each district, for which the local landholder had to pay a cess. In time, however, the extension of the Imperial post rendered these district establishments unnecessary and they were finally abolished in 1904.

The most important step in connexion with the Post Office was taken in 1854 when postage stamps were introduced. In that year cheap postage rates, irrespective of distance, were fixed for the whole country, and a single Director-General was appointed to take charge of the department. Since then, the Post Office has steadily developed and has assumed very many functions besides the conveyance and delivery of correspondence. The carriage of parcels was undertaken from 1854, money orders are now paid at the residences of payees, savings banks have been opened all over the country, quinine is sold and the department assists Government in its loan operations. In the Punjab the Post Office undertakes the payment of military pensions.

Owing to the enormous size of India (including Burma) the work of administration has to be rather more decentralised than in smaller countries. Under the Director-General there are eight Postmasters-General with considerable independent powers, who are responsible for the administration of the eight postal circles into which the country is divided. The railway Mail Service used to be under one Inspector-General, but it has been found necessary in recent years to divide the general supervision among three officers.

I will give a very few figures to illustrate the development of the Post Office during the last 10 years.

	Millions.
Letters, postcards & packets	940 to 1330
Parcels	8 to 12½
Newspapers	55 to 78

Since the inception of the money order system in 1881 the value of money orders has risen from 46 to 800 millions of rupees and in approximately the same period the Savings Bank balances from 28 to 222 millions.

There were at the end of the last financial year 19,500 post offices in India to serve a population of 310 millions. This means about one post office to every 16,000 people, but it must be remembered that not more than 7 per cent. of the population is literate and that the standard of literacy is very low. Probably not more than 3 per cent. of the population can write a letter or understand the meaning of a newspaper article. One can easily imagine, therefore, what the Indian Post Office will grow into with the development of education, when, say, 20 per cent of the population begin to write letters.

India has to face the same postal problems as other countries, but these are greatly complicated by the diversity of races, the large number of scripts in which the various languages are written, the illiteracy of the great majority of the people and the difficulty of communications. It is impossible to get any staff, except in the most important offices, which can deal with all the scripts used, and recourse has to be made to one of the Returned Letter Offices, of which no less then seven are maintained. To benefit the ignorant population, the system of paying money orders in cash at the residences of the payees has been adopted. This system is expensive and fraught with risk, though on the whole, it has worked well and it is undoubtedly an enormous convenience to the poorer people and especially to those who live in villages at a distance from a post office. It entails, however, great responsibility for the postmen, who have frequently to be entrusted with considerable sums of money. In large towns special sets of postmen are kept for this purpose only, and it can be easily conceived what ample opportunity for fraud arises when the payees can neither read nor write. Communications in India are steadily improving and there are now about 36,000 miles of railway services, 10,000 of mail cart lines and 3,000 of motor lines. Despite these improvements there are still 90,000 miles over which mails are carried by 26,000 runners. The romance of the Post Office lies with the mail runners. They are largely drawn from the lowest castes and least civilised races of India. They are a superstitious class, ready to face wild beasts and wandering criminals, but also ready to go miles out of their way to avoid an evil spirit in a tree. With them, the mail bag is a

fetish which must be protected at all costs. Dishonesty among them is very rare, and they are wonderfully true to their salt, which seldom exceeds 20 shillings a month. Not a year passes that does not take its toll of runners who lose their lives in the execution of their duty. It may be a tiger, a swollen river, an avalanche in the Himalayas, a gang of robbers. The work goes on just the same; the mail goes through whatever happens.

A most interesting article upon the romance of the Indian Post Office was written some years ago by Sir Arthur Fanshawe, Director-General of the Department, in *Blackwood's Magazine*, and in this he gives full credit to the loyalty of these faithful servants of the Post Office.

The true spirit of the service is nobly expressed by Rudyard Kipling:

Is the torrent in spate? He must ford it or swim.
Has the rain wrecked the road? He must climb by the cliff.
Does the tempest cry 'halt'? What are tempests to him?
The service admits not a 'but' or an 'if.'
While the breath's in his mouth, he must bear without fail,
In the name of the Empress, the Overland Mail.

There is no branch of the Government Service that comes in such close contact with the people as the Post Office. Its officials are consulted in all kinds of family troubles. The village postman is a kind of perambulating branch office. He receives and delivers correspondence in the villages on his beat and pays money orders. He sells stamps and quinine and being a local man he has to face a certain amount of public opinion if he does not act fair and square. In some hill tracts he is provided with a bugle to announce his arrival and to the inhabitants of these he brings news of the outside world, he writes their letters, reads their postcards and explains to them his own conception of the mysteries of the money order system.

The money order system in India enters largely into the life of the people. It is the sole means by which the poorer classes remit money and the introduction of rent and revenue money orders has proved a great boon to the agricultural classes. The fact that last year over 33½ millions of money orders were sent shows how popular the system is. Many of these money orders are Value Payable orders sent in payment of goods despatched under the Cash on Delivery system. In 1921–22 a sum of over 220 millions of rupees was collected by the Post Office and paid to tradespeople for merchandise sent through the post. In India, where there are few large retail firms outside the Presidency towns, the Value Payable Post has proved an inestimable convenience to the up-country purchaser, who pays the Post Office for his purchases on receipt and is put to no further trouble.

Like everything designed for the good of mankind, the Value Payable Post is not altogether an unmixed blessing and is a source of continual worry to the officials of the Department. The weak point in the system is that people have to buy articles without seeing them and if they are disappointed in their purchases, they are inclined to think that the Post Office is at fault and to demand their money back. It is customary in India for certain ladies to dispose of their garments through the medium of the advertisement columns of the leading newspapers. The dresses are always by Paquin and quite new; the hats are the latest from Paris. This is the seller's point of view. How different that of the purchaser! As Postmaster General, I have received many a bitter complaint of the filthy rag which was received under the designation of a new Paquin gown and for which I was personally held responsible. The Value Payable Post also suffers from that trust in Providence which is a peculiar feature of the Eastern mind. Although strictly forbidden by the rules of the Post Office, the small Indian trader sends out numbers of articles as value payable to persons who have not given any orders for them, trusting that some of them will be accepted by a confiding public, and, strange to say, he manages to do a certain amount of business in this way. On the other hand, many people are quite ready to order things from shops which they hope to be able to pay for upon arrival, but unfortunately for the firms that supply them, these hopes are not often fulfilled. The Indian schoolboy, who is very like all other schoolboys in the world in this respect, is specially tempted by the flashy catalogues issued by the Cheap Jack firms of Calcutta and Bombay and when, in a fit of enthusiasm, he orders a five rupee watch, it doesn't follow that he has the money or is even likely to have it; but his self-

esteem is satisfied by the mere issue of the order and as for his ability to pay when the time comes, it lies on the knees of the gods.

The result of this trait in Eastern character is that about 15 to 20 per cent. of the value payable articles have to be returned to senders.

The first telegraph line in India was opened between Calcutta and Diamond Harbour, a distance of 30 miles, in 1851; there are now about 412,000 miles of wire, including cable. The father of the electric telegraph in India was Sir William O'Shaughnessy Brooke, F.R.S. In 1839 when he was merely Dr. O'Shaughnessy, Professor of Chemistry in the Medical College of Calcutta, he used to occupy his leisure time with experiments in telegraphy and in that year he erected near Calcutta the first long line telegraph ever constructed in any country. The line was 21 miles in length and had a river circuit of 7,000 yards. Dr. O'Shaughnessy's experiments, however, were far in advance of the views of the Board of the East India Company and it was not until 1849, by which time telegraphy was a proved success in Europe, that we find any move made in India. Finally, in 1850, sanction was given to the erection of a line between Calcutta and Diamond Harbour, which was completed in 1852. This line was of no great length, but its construction involved peculiar difficulties. The low-lying delta of the Ganges is exposed to violent storms and much electrical disturbance. Moreover, the river Hughli is not only a broad and rapid stream with an ever shifting bottom but it is the highway of navigation to Calcutta. Telegraph cables, before the days of steam, were therefore peculiarly liable to damage from the anchors of ships and small craft, which were at times forced to drag anchors owing to the dangers of navigation. With these difficulties to face Dr. O'Shaughnessy, who had little in European practice to guide him, used heavy iron rods instead of light wire as a conductor. These were welded together and slung on bamboo poles or buried in cement and resin according as they were run over or underground. No insulators were used. The cables were wrapped in gutta percha, cased in lead and protected by chains.

The success of this line was so convincing that Lord Dalhousie persuaded the Court of Directors to sanction the immediate construction of lines between all the important towns. This prompt decision to extend the telegraph in India without delay had an importance that he little dreamed of at the moment. Had this extension scheme been discussed in the usual leisurely official way valuable years would have slipped by and the telegraph service would not have been the organised and efficient aid which it proved when the Mutiny broke out in 1857. It has been truly stated that at this period "the Electric Telegraph saved India."

The extension of telegraph lines to rural areas through the agency of the Post Office was decided upon in 1883 and gradually small post and telegraph offices were opened all over the country. The number of such offices on 31st March 1922 was 3,437 and the traffic sent by them about 10½ million messages. The operators in these offices are postal clerks and are quite distinct from the General and Station Service telegraphists who man the Departmental Offices. The latter are picked men, who get a very careful training in telegraphy. Selections are made from their numbers for the engineering branch and in recent years the very highest posts in the service have been opened to these recruits. It has been found that by making the telegraph service a *carrière ouverte* the ordinary operator is encouraged to use every effort to improve himself and to keep abreast of modern developments in telegraphy. These modern developments require great technical knowledge and skill in dealing with delicate apparatus. Any operator can manipulate and adjust a Morse instrument and circuit, but it is a very different proposition to adjust Baudot instruments which send three or even four messages in each direction over a single wire at the same time. The very highest technical skill is wanted. In fact, modern telegraphy is becoming more and more dependent upon the technical expert. The operator in most cases has merely to use a typewriter or handle a simple transmitting key. In India many lines are over 1,000 miles in length; they are all over ground and subject to perpetual disturbance. In forest tracts they are liable to be broken by falling trees and in low-lying country to be submerged during the rainy season. Low insulation is a common trouble. This is often due to spiders' webs, salt deposits on the wire, electric storms and other unavoidable causes. The maintenance of these long lines is a constant source of expense and

anxiety, as the communications of the whole country depend upon their being kept in good order and with the introduction of high speed telegraphy proper maintenance is becoming a more and more important factor. The high-speed apparatus used in India for many years was Wheatstone, which, in combination with the Creed Printer, gave excellent results and was able to work over long distances. This system is being gradually replaced by the French Baudot apparatus, which with the aid of the Murray Transmitter is really the triumph of modern telegraphy. By careful synchronisation as many as eight messages can be sent at the same time over a single wire. We have not got so far as this in India yet, but good results have been obtained with four and even six armed Baudot, that is six and four messages respectively. With such a system, the saving in wire mileage can be easily imagined. Baudot, however, is difficult to work unless the wires are in good order and in the last few years copper wires have been erected on all the main circuits in order to facilitate Baudot working. Copper, unfortunately, is a very desirable commodity in India, and the theft of copper telegraph wire is a regular profession in certain parts. Last year we had to replace the copper wires leading out of Calcutta by heavy iron owing to the continuous thefts.

The problem for the telegraph engineers nowadays is not the erection of new wires to meet increased traffic on the main circuits but the greater use of existing wires by multiplex high-speed instruments at the terminals. When one long wire extending over 1,000 miles can be got to do the work of four, think of the economy and the saving in maintenance charges. I do not intend to-day to enter into a discussion upon high-speed telegraphy. It is an intensely fascinating study and one which requires a knowledge which I do not possess. I have only referred to it in connexion with its enormous importance to our communications in a vast country like India. With modern apparatus increased traffic does not necessitate either more wire circuits or more staff; it does demand, however, the highest technical skill in the terminal and repeater offices.

The Cable Communication to India was first undertaken by the Red Sea and Telegraph to India Company of 1858, which was subsidised to some extent by the British Government. Long distance submarine cables were not, however, laid until 1866 when the success of the Atlantic cable, 2,000 miles in length, was established. Gibraltar, Malta, Egypt, India, China and Australasia were linked with Great Britain between 1866 and 1870 by the Eastern Associated Telegraph Companies. Two land lines were also constructed, the Indo-European via Persia, Russia and Germany, and the Turkish line by cable between Karachi and Fao and then through Mesopotamia and Constantinople. Cables to Penang, Singapore, Hong Kong, and Australia, were laid in 1871 and 1872. The amalgamation of the various companies operating this side of India and their registration as the Eastern Telegraph Company conduced to bring about an efficient working of the cables. The further registration, in 1873, of the Eastern Extension Australasia and China Telegraph Company, absorbing the companies which existed east of India, and the duplicate and triplicate lines since laid between many points have decided the system which enables us to communicate with even our remotest colonies with such admirable facility.

During the War, both the land lines between Europe and India failed and the whole burden of a very heavy traffic fell on the Eastern Company's cables. It must be remembered that during this period the State traffic increased enormously and, owing to the uncertainty of the post, all commercial business was done by telegraph. The strain on the cables was very heavy, but the Company's staff worked with untiring zeal and though there were unavoidable delays at times, during those four years the cable communication between India and Great Britain never failed.

There are at present four cables between Bombay and Suez, a cable from Aden to Colombo direct and a cable from Aden to the Seychelles and thence to Colombo and the Far East. Madras is connected with Penang by two cables, so that India is in a very strong position. Not only has India a great deal of telegraph communication of her own both to the West and East, but she forms the transit link for many telegrams between Europe and countries to the East of her. For the handling of this transit traffic two wires between Bombay and Madras are placed at the disposal of the cable companies and the through traffic is handled entirely by them. This

method has proved most satisfactory; it saves delays and references regarding an enormous number of messages which pass across India. The growth of telegraph work since 1869 has been :—Inland from 311,000 to about 16 millions a year; Foreign, from 43,000 to about 3 millions a year.

The development of telephones, both trunk and urban, in India has been very slow. Licensed companies have been allowed to operate in the cities of Calcutta, Bombay, Madras, Rangoon and Karachi and just when expansion was about to take place, the War intervened and they were greatly hampered by the difficulty of obtaining apparatus. These companies, which had licenses subject to determination at intervals of 5 years were naturally unwilling to incur large capital outlay without some security of tenure. They have now been given 20 years licences and are all installing new plant to replace the present out of date systems and to meet the large increase in connections demanded.

The systems in up country towns and the trunk lines are all maintained by Government and although there has been a steady expansion in the last five years, telephonic communication is still in its infancy. Automatic telephone exchanges have proved a great success in Simla and Lahore and installations are now being erected in other places. These installations, especially the small ones, are particularly suited to Indian stations, where there are few subscribers and where it does not pay to keep operators on duty for 24 hours. It is a matter of experience that an operator who gets few calls at odd times becomes inattentive and he is very likely to be asleep or away getting his tea when most urgently required. The automatic telephone obviates all such inconveniences. It is always ready and enables the caller to get directly on to the number required. Wherever it has been introduced, there is an immediate increase in the demand for new connections and its great popularity is now assured. Trunk lines are gradually spreading over the country. The long distances in India and want of business enterprise have hampered their extension. When it was first proposed to connect the vast coal fields near Raniganj by trunk with Calcutta, a distance of about 150 miles, few of the companies were willing to come forward and guarantee a minimum number of calls.

Now, however, that the lines have been constructed, they are used extensively and three trunks are kept very busy. Owing to the transfer of the winter head-quarters of the Government of India from Calcutta to Delhi, a system of trunk lines was set up between Simla and Delhi. These have now been extended throughout the Punjab and North-West Provinces and almost all the important towns in the north-west of India are in telephonic communication. The next step is to continue the trunks to the great commercial centres, Bombay and Calcutta, and steps are being taken to have this done. Comparisons of the number of telephones to population have no real meaning in a country like India, where over 80 per cent. of the population consists of peasant cultivators and labourers, who would never in any circumstances use telephones. The figures for some of the leading countries are :—

		Persons.
United States	1 telephone to every	8
Canada	1 ,, ,, ,,	10
United Kingdom	1 ,, ,, ,,	47
India	1 ,, ,, ,,	8,455

so, judged by statistics, we must be considered as being among the backward countries.

Another branch of the service that is still in its infancy is that of wireless telegraphy. In 1918 there were 30 stations, including ship stations. Of the fixed stations the most important are those on the coast, i.e., Bombay, Karachi, Calcutta, Rangoon, Madras and Port Blair. These stations do a great deal of regular traffic with ships and Port Blair is in continual communication with Rangoon, as this is the sole means of telegraph for the Andaman Islands. During the war the inland stations were taken over by the Army and were practically idle. They never did any real work. The apparatus, which is of the spark type, is out of date and the staff had deteriorated. Although it has not been possible to refit more than a few stations with continuous wave apparatus, all stations have to handle a certain amount of commercial traffic every day. On the whole, it has been found that in a country where there is ample means of communication by the ordinary telegraph systems, there is little need of wireless telegraph for internal traffic, and it has now been decided to close down a number of the larger inland stations which are, after all,

an expensive luxury. They do possess a certain strategic value in case of wires being cut, but where ways and means have to be considered, it is preferable to maintain only stations that are essential and to equip these properly so as to make them really efficient. That is the aim of our Wireless Branch. Until last year, communication by wireless was at hand speed and very slow. Experiments in high speed have been made and several high-speed circuits will be established shortly when the traffic demands them. The most important of these is between Rangoon and Madras, between which places direct communication is badly wanted. The present land lines go right away by the north of Burma and across the Ganges Delta, where they are subject to frequent interruption.

The most important part of our wireless work is research. India has to face that terrible obstacle to Wireless known as "atmospherics" and at certain times of the year these atmospherics make it quite impossible to hear any signals. Our research branch, which has been dealing with the problem for some years, is steadily overcoming the trouble and though it may not be possible to eliminate atmospherics altogether, there is every hope that they will be soon overcome to such an extent as to render signalling possible at all times of the year.

I do not intend to dwell upon the much discussed question of the Indian Imperial Wireless Station. This was commenced in 1912 and abandoned. Some of the masts are still standing on the ground near Poona and very lonely and disgusted they look. Such a station would have been invaluable during the War. The Indian Government have always been most anxious to obtain direct wireless communication with Great Britain and to form part of a great imperial wireless chain, but they are not in a position to incur the heavy outlay involved and the delay is largely due to financial considerations. The matter has been under discussion for some time with the British Government and it has now been decided that private enterprise will have to undertake the task.

In a country where there is seldom perfect peace, it is only natural that the Post Office must accustom itself to war conditions and the Field Postal Service has been a feature of the Indian Post Office for more than sixty years. During that period there have been over forty wars and expeditions extending from Burma to the Mediterranean, and as postal arrangements were required for the forces engaged, the Field Post Office system in India has been steadily developed and perfected and is now recognised as part of the military organisation of the country. In 1914 when the Great War broke out very severe demands were made upon the Post and Telegraph staff. A large contingent was sent to East Africa consisting of about 900 men; a big postal staff accompanied the Indian Expeditionary Force to France. In 1816 Mesopotamia, so far as Indian troops were concerned, was the most important theatre of war and the whole postal and telegraph work of the country was carried on by staff from the Department. The telegraph staff was lent to the Army Signal Service, but the postal staff formed a separate unit under the control of a director subject to the orders of the Director-General in India. The magnitude of the work may be gauged by the average monthly figures for 1918. These were :—

Letters and postcards	..	12,000,000
Parcels	..	70,000
Money orders	..	67,000
Value of money orders	..	R3,000,000

Next in importance to Mesopotamia came the Indian postal service in Egypt, Palestine and Salonika and in these places the India Office worked side by side with the British Army Postal Corps. Field services were also established in Eastern and Southern Persia and in Aden. The Department is reasonably proud of its achievements during the Great War. A large number of personal distinctions were conferred and over 500 men mentioned in despatches. The best proof of their work, however, is the high reputation which the Post and Telegraphs of India have earned among all branches of the Army.

No paper upon the Indian Post Office would be complete without a reference to that fine company which has carried our mails to and fro between London and Bombay since 1842. The weekly arrival and departure of the P. and O. mail steamer is an event in India. It is the great link with the old country and means to the British residents more than words can describe. During the War the service had to be made a fortnightly one, and it is a wonderful record that, despite the loss of eight mail steamers, throughout that whole period the fortnightly service was maintained with extraordinary regularity.

The Sea Post Office was for many years a great feature of this service. It involved an expensive sorting staff working between Aden and Bombay, which was idle for a considerable portion of its time. However, when the War broke out the Sea Post Office had to be abolished and all the sorting of the foreign mails is now performed at Bombay in the new office which is alongside the landing stage. A staff of about 300 men deal with the mail on arrival and in four hours it is ready for despatch to the various quarters of India by special trains which are drawn up at the pier station. The coasting mail services and the Persian and Burma services are efficiently carried out by the British India Steam Navigation Company under a general contract with the Post Office.

Various suggestions have been made from time to time to carry the mails by air, but up-to-date, nothing like a reasonable proposal or a firm offer has been made to the Government of India. In 1920 I made an experiment of carrying mails by air between Bombay and Karachi in connexion with the arrival and departure of the English mail steamer. In all, 18 flights were made. The advantage to the public of Karachi was about 15 hours in time, but the amount of mail carried was insignificant and the service was abandoned. The actual flights were made by R.A.F. machines piloted by R.A.F. men and were very successful. Only two failures involving serious delay occurred and as the route was a new one covering 500 miles, with only one intermediate landing ground, at Rajkot, the result was very creditable. We have also heard a great deal of an air service from Cairo to Karachi via Bagdad and Burma. The India Government is prepared to maintain the landing grounds in the Persian Gulf and to place the Karachi Aerodrome at the disposal of such a service. With respect to these air services to India, there is no hope of any financial success unless they go through between England and India. The public will not pay any extra charge on letters to be taken at high speed between Cairo and India and by the ordinary mail steamer the rest of the way. The saving in time is too small and in these days when all important commercial transactions are settled by telegram, the necessity for saving a few days out of 15 or 16 in the post is not of very great consequence. The efforts to establish air services in India up to date have certainly failed. The cost compared with the possible revenue has been too high. In the beginning the serious mistake was made of trying to introduce commercial aviation with machines built for war purposes. One might just as well try to carry out the P. & O. contract at a profit with cruisers and destroyers. When a really good commercial aeroplane, economical in the use of petrol, has been designed for India, I have no doubt that air services which will pay their way can be established.

We now come to the thorny question of rates. There has not been so much discussion regarding telegraph as regarding postal rates, although the former are nearly as important. The reason is, I suppose, because the latter touch all classes of the community far more closely. Ever since the days of Rowland Hill, the cry in the British Empire has been for cheap postage, and by cheap postage we mean the Imperial penny post. This rate was in force before the War but the steady depreciation in the value of money led Government to reconsider the position.

The enormous rise in wages and in the cost of all services made it necessary to raise postal rates, if the Post Office was not to prove a heavy burden on the country's revenues, and we arrived at the startling position of a 2d. letter post and a 1½d. postcard in Great Britain. Telegraph and telephone rates were considerably increased at the same time, and although there was a great deal of grumbling the revised rates were accepted.

In 1920 at the International Postal Congress in Madrid the permissible initial international union letter rate was raised from 25 to 50 centimes and the postcard from 10 to 30 centimes. In fact, all countries were in the same position. They could not, with the previous rates, make their postal revenue cover the cost of the services. The result has been a general increase in postage rates in Europe and European dependencies.

In the United States and South America much opposition was offered to the proposed increase of the Union Rate and a minor union was formed, which agreed to the acceptance of internal rates of postage for all correspondence between its various members.

In India ever since 1854, when a fixed rate of postage irrespective of distance was laid down, the initial rate for letters was

½ anna. At first the initial weight was small i.e., ½ tola or 1/5th ounce, but it enabled the poor man to send his light and flimsy letter at a very small cost. The weight was subsequently raised to 1 tola or 2/5ths ounce when the ¼ anna postcard was introduced. For many years India was able to maintain its postal service at these rates, without any loss. It was run economically, perhaps too economically, but in 1919 things changed. Prices increased immensely, and the staff, which was admittedly underpaid, demanded a fair wage. Committees were appointed to deal with the question of the pay of both the Telegraph and Postal staffs and on their recommendation the pay of the former was increased by about 50 per cent. and of the latter by about 100 per cent. As a result of these increases the Post Office began to show a heavy deficit and the Finance Department became alarmed. In 1922 the initial rates were doubled to 1 anna per ounce for a letter and ½ anna for a postcard. These rates compare very favourably with those in Great Britain and are, in my opinion, fully justified. Our distances in India are six times as great as in this country, we don't get the same volume of mail to handle and much correspondence has to travel many miles by runners' lines, over which any appreciable increase in weight involves the employment of an additional runner at each stage.

It is generally accepted that the Post Office in any country should just pay its way, but I do not consider it any great disaster if it fails to do so. Cheap postage is such an inestimable advantage to the life of a country, both on its social and business side, that the actual loss in maintaining the service may be more than counterbalanced by the general gain to the community.

It has been found by experience that high postage seriously interferes with the distribution of business and trade circulars, and it is possible that in this way the gain of a million pounds, say, to postal revenue may mean the loss of 10 million pounds worth of trade orders. This may be a gross exaggeration, but it is an argument for cheap postage quite irrespective of its results in the Department itself.

With the introduction of penny instead of halfpenny postage into India last April, there was a very serious diminution in the volume of mail matter. It amounted at first to about 25 per cent. I am glad to say that the position is steadily improving, and I trust that even with the revised rates, we shall return to our normal figures very shortly. The increase in revenue is good and will enable the Department to pay its way and carry out many necessary developments. The development most required is the further extension of the post and telegraph into rural tracts and there is a very urgent demand for this from the people and from their representatives in the Legislative Assembly. In India the opening up of rural tracts to postal and telegraph communication is always performed at a loss, but it is the burden of pioneer work, which is one of the essential duties of the Department and one which has to be undertaken.

In fixing postal rates the initial rate is the important item. However small the weight carried for this rate, be sure that the public will adapt itself to that weight in an incredibly short space of time, and that over eighty per cent. of letters will come within it. There is no doubt, however, that the reintroduction of the Imperial penny postage, which might also be extended to a few other countries, would be an immense mutual advantage, and would be hailed with approbation by all our dominions and dependencies.

With respect to telegraph and telephone rates, it is difficult to lay down any definite standards. The Indian public are particularly critical of the triple rate for urgent cables. This rate was laid down by the International Telegraph Union, and messages of this class take priority after Government Priority and Urgent Service traffic. We always resisted the introduction of urgent cables in India until our hands were forced by the transit traffic. Many urgent messages are received from and sent to the Far East which have to pass through Bombay and Madras. Under the International Convention we cannot refuse to accept these messages, and the result was that the ordinary full paid cables, originating in London, had to wait until these urgent messages were disposed of at Bombay and Madras. We were, therefore, forced to give Indian merchants the right to send and receive urgent telegrams at triple rates in order to enable them to compete with other countries. Personally, I should like to see this triple rate class of message abolished in normal times, but to do so would necessitate the concurrence of all the important

states in the Union, a concurrence that I fear it would not be possible to obtain.

The most interesting extension of the postal and telegraph system in India during the past year has been the opening up of communication with Tibet and Afghanistan. Tibet has always tried to remain behind a veil, and no proper service either postal or telegraph ever existed beyond the frontier trade station at Gyantse. Now both a postal and telegraph line connect Lhasa with India. The latter was constructed by the Indian Government last autumn at the instance of the Dalai Lama, a most enlightened minister. He spent the first few days sending congratulatory messages to the Viceroy and other officials of the Indian Government. In the ordinary course, direct postal and telegraph communication might have been opened with China on the other side, to the exclusion of India, and the Indian Foreign Office is to be congratulated upon the establishment of this important link, which is certain to lead to closer political relations with India's most important neighbour on the North-East Frontier.

Owing to the conclusion of the treaty with Afghanistan, involving the residence of a British minister at Kabul, a regular postal service has now been established between Peshawar and Kabul. Telegraphic communication during the past two years has been confined to wireless for State messages only, and this is frequently interrupted owing to breakdowns on the Afghan side. During the past six months a party sent from India has been constructing for the Afghan Government a telegraph line which will extend from Landi Khana on the Frontier to Kabul via Jallalabad. This line is now practically completed. The Afghan Post Office is not yet properly organised. No rates of postage are published and letters are taxed upon delivery. As Afghanistan has not yet joined the Universal Postal Union, it is impossible for correspondents in other countries to do more than stamp their letters to India. These letters are handed over to the Afghan Agent at Peshawar for despatch to destination. What further charges are levied upon them it is impossible to say, but the general uncertainty interferes with regular correspondence. It is sincerely to be hoped that Afghanistan, which now desires to enter into the community of nations, and which has accepted representatives with the Governments of all the great countries, will soon join the Postal Union and announce its rates to the world.

Before closing my remarks I should like to say a few words about the personnel of the Indian Posts and Telegraphs. Since 1913 the whole department which is responsible for postal, telegraph, telephone and wireless work is under a single head, the Director-General. The Chief Engineer, Telegraphs, is his right-hand man and has a great deal of independent authority. The Wireless Branch has now been separately organised and placed under a Director and a special officer under the Chief Engineer is in charge of Telephones. The staff consists of about 120,000 persons. There are many unions, from unions of officers to unions of postmen, but the only really strong and effective one is the Telegraph Association. This is a well managed body. It embraces nearly all the superior staff of the purely telegraph side recruited in India. It has funds and an excellent organisation under a most capable general secretary and I am glad to say that its influence is directed to promote the good of the telegraph service. In recent years when industrial strikes were the order of the day, the Indian Posts and Telegraphs had only three strikes, all among postmen, and the only serious one was at Bombay. This was purely political and was organised by the Non-co-operators. The men had really no grievance and when they saw that the Department did not intend to yield one inch to their demands, they begged to be allowed to return to duty. On the whole, this large staff has worked with steady loyalty and devotion to duty and I attribute this largely to the fact that the Department offers a free scope for advancement to its employees. A clerk may rise to be a postmaster-general, a postman may rise to be a postmaster and I have always laid the greatest stress on the personal influence of officers with their men. Punishments are, I admit, necessary to deal with delinquents in all services, but automatic punishments regardless of circumstances do more harm than good.

It is often much easier to bring a man back to the right path by having a straight talk with him than by imposing a fine which he cannot afford to pay. As for the really bad men, get rid of them quickly; they are the tares among the wheat and will never do any good. Experience goes to show that when human sympathy and the

personal touch replace rigid rules, greater zeal, greater fidelity and better work are ensured.

There is, as you are aware, a persistent and natural demand in India to Indianise the services. In the Post Office Indianisation began many years ago and there has never been any distinction of race in the matter of promotion to the higher appointments. In fact most of these are at present held by Indians and very efficient and trustworthy officers they have proved. I think it is purely due to this elimination of race distinction both in the matter of appointment and pay that the Department has been able to work so smoothly in troubled times. Loyalty to the service is the doctrine which we preach and in our work we try to do the greatest good to the greatest number.

DISCUSSION.

Sir Arthur U. Fanshawe, K.C.I.E., C.S.I., C.V.O., said that he had listened with great pleasure and interest to a paper by a former colleague, who was now Director-General of Posts and Telegraphs. Some years ago, when he was himself Director-General of the Post Office in India, Mr. Wanamaker, a great Postmaster-General of the United States, came to see him, and took away under his arm, in the shape of a Blue-book, a review of ten years' postal administration. Mr. Wanamaker's remark was, "I tell you, sir, I shall read your book as if it were a novel." There was a very real element of romance, of what might be called the novel in postal work in India, and he (the speaker) felt this particularly while Mr. Clarke was telling his story. He had told them how honest and courageous were the mail runners. He might have added that in many parts of India these men, among the humblest servants of the Government, believed that just because they were servants of the great Government, they themselves shared the good luck that belonged to the British *raj*. He would like to offer a few remarks about the financial position of the Post Office. When he became Director-General, nearly thirty years ago, the department was not a revenue-producing one; it hardly paid its way. That was a dangerous position, for there were reforms and improvements to be introduced, all of which would cost money, and such proposals were apt to be looked upon unfavourably by the Government if those suggesting them were not able to say where the money to carry them out was to come from. Accordingly a determined effort was made to ensure that the Post Office should pay its way. During the thirteen years in which he was responsible, the department every year showed a surplus. He claimed no credit for that achievement, though the Government gave him some credit. The fact was the material progress of the country had been going on quickly; education had spread, and more and more use was made of the Post Office. But the surplus made all the difference and the Government decided that such surpluses should be devoted to postal ends, a very wise principle. He hoped—and here he did not quite agree with Mr. Clarke—that the Post Office would soon again become a revenue-producing department. For a Post Office to be successful, it was most important that it should pay its way. He sympathised fully with Mr. Clarke's exceptional difficulties in having to raise the pay of establishments wholesale on account of the rise in cost of living, which had crippled the department and led to the introduction of higher rates of postage. He hoped that all the various grades, understanding what had been done for them, were now working contentedly and loyally. He had heard recently of some increase of theft and trouble leading to loss of public confidence; he thought these stories must be exaggerated, but it would be useful to have an assurance from Mr. Clarke on the point.

Lieut.-Col. I. E. A. Edwards, C.M.G., Air Force Retired, Deputy-Director of Air Transport, Air Ministry, read the following note from Major-General Sir William S. Brancker, K.C.B., Director of Civil Aviation, who was unable to be present:—

"Mr. Clarke has touched the keynote of air transport at the very beginning of his lecture when he says the postal service in India, like that of other countries, had its origin in the necessity of maintaining communications throughout the various parts of a great empire. Communications have been the life-blood of every empire in the history of the world, and to-day the life-blood of the British Empire lies in its communications. Aviation offers a rapid and frequent means of communication between the Home Country and our Overseas Dominions.

"The lecturer has described the experiment of carrying mails between Karachi and Bombay, and I think that the results of this experiment bring out two main facts about air transport: (1) it cannot succeed commercially, except over long distances, and (2) an enormous amount of publicity and education is required before really appreciable traffic can be obtained. To-day, technically, air transport can be run reliably and safely; its great handicap is the difficulty of obtaining money. It cannot pay its way until a proper volume of traffic has been obtained, and money is necessary to tide it over its lean years until it has proved its qualities and gained the confidence and the patronage of the general public. The Indian Government, like most other Governments.

is obsessed by its financial difficulties, and, although it realises vaguely that its prosperity depends on the efficiency of its communications, it cannot visualise the enormous importance of aviation to-day, and in the near future, as a factor in this prosperity. There is little doubt in my mind that, if certain air services were established in the British Empire without any sort of guarantee regarding profits or takings, they would become commercial propositions in a very short time. The trouble to-day is that money cannot be obtained to establish these services. Governments require proof as to the commercial success of such services before they are established, and, naturally, it is impossible at present to give this proof. If India had a dozen more men of the same calibre as Mr. Geoffrey Clarke, air transport would become a flourishing means of communication in the Indian Empire before five years were out.''

Colonel Edwards added some observations of his own. With regard to the development of an air mail service in India, he thought the main difficulty had been, not that there was no company prepared to put up a tender, but rather that the Government was looking to the home Government to give a lead. In saying this, he did not include Mr. Clarke, because during the whole of his (the speaker's) time in India, when he was trying to negotiate these services, nobody gave him greater assistance than did the reader of the paper. England and India were not quite in the same position so far as aviation was concerned. In England the main bugbear was fog. Fog meant unreliability, and affected the main principle of the postal services. In India there was no fog, except occasionally during the monsoon. India offered the most wonderful possibilities in the development of air transport. From Bombay to Calcutta the train took about 52 hours. The time taken by the air service—by a service actually worked out and ready to be put into operation, via Allahabad—was 14 hours. An even greater saving was effected in the journey from Calcutta to Rangoon. Under the present system the journey occupied from three to five or six days; by air it would take nine hours. The whole distance from Rangoon to Bombay could be covered in about 26 hours, allowing for stops for re-filling, changing passengers, and so forth. Another difficulty arose from the fact that while companies were prepared to run the services in India to-day, they wanted the condition that the Government should go to the expense of putting down the ground organisation necessary. The actual cost of establishing the ground organisation from Karachi to Calcutta and to Rangoon, viâ Allahabad, with a branch from Allahabad to Bombay, was approximately 30 lakhs of rupees. The distance covered by the air service would be 2,200 miles, whereas for a similar sum only 15 miles—approximately—of single line of railway could be constructed.

The Chairman said that the cost was two lakhs a mile for a single railway.

Colonel Edwards said that the fifteen miles appeared a small matter against the 2,200 miles of air service. If this ground organisation were established, the lines would be forthcoming. He thought he was well within the mark in saying that even at the present day, with the ordinary commercial machines available, goods or mails could be carried at a rate of four rupees per ton mile, and that rate was coming down very rapidly. Within the next few years it would be considerably less than Rs.4 per ton. The mails carried at that rate would not represent a very big surcharge; he thought the work could be done at from two annas to three annas surcharge, and certainly a big profit would be made if the surcharge was four annas.

Lieut.-Col. Walter A. J. O'Meara, C.M.G., late R.E., said that by accident a great part of his life had been spent in connexion with the telegraph service, unfortunately not in India. He had some slight telegraph experience with the Bengal Sappers and Miners in India many years ago, but later, in Burma, whilst serving with the Burma Expeditionary Force in the campaign of 1885-1886, he saw something of the practical working of the telegraph service, which was looked after by officers of the Indian Telegraph Department, not military, but civilian officers, who did work which was very valuable to the small operating forces scattered over a wide extent of country. In the Burmese theatre of war, there was but one main telegraph line; it was very often cut by the enemy, who coiled pieces of the wire into a cylindrical shape and used them as "slugs" in their muskets. However, the telegraph communication, when interrupted by the dacoits, was always speedily restored. Many years later (in 1909), he had the privilege of investigating the telegraph systems in the United States of America, and still later (in 1912 and 1913), of going over a great part of Europe inquiring into the Continental telegraph and telephone departments and systems. He was glad that Mr. Clarke had dealt with staff matters, for the most important part of the telegraph system was the personnel and its organisation. If the recruiting of the personnel was on right lines, and its organisation sound, the foundations of efficiency were thereby established and secured. He would like to suggest that when Mr. Clarke's paper was printed, a chart might usefully be appended to show the reader what the organisation of the Indian Telegraph Department was. He had

had on occasion to give evidence on telegraph matters, and among the things one very much wanted to know when preparing to give evidence was the organisation here, there and everywhere. He found practically no information in English publications which showed clearly what the organisation of Government departments was. There was, on the other hand, an Italian official publication in which he found—in the Italian language, of course—a description of the organisation of the posts and telegraphs of every European State, and here there was some information regarding the British Post Office, although briefly summarised, but none concerning the Indian organisation. It was very important that, for the purposes of a comparative study of the subject, the whole of such information should be collected together. Mr. Clarke had spoken of the *carrière ouverte*, of which they were all in favour, but he would like to know a little more as to what it meant in this instance. Did it mean that an officer from one department or branch could go into another, or had he to remain in the branch he originally entered? He hoped that this idea of the *carrière ouverte* did not mean the abandonment by the Indian Government of the requirement of that very high standard of technical education which was provided for the officers of the Indian Telegraph Department in the days when the Engineering College at Coopers Hill existed. In European States the staff in the public departments is often divided into three main grades, the so-called "Higher," "Middle" and "Lower Careers." The "Higher Career" is open to men with a university education, or its equivalent in cases where there was no university, and the "Higher Career" idea was carried much further abroad than in this country, as therein was included the technically trained staff. In this country, unfortunately, the idea was that university men were wanted for the non-technical work, but that anybody would do for the technical work. On the Continent, the contrary view prevailed, and the practice was different. In many countries abroad, they had separate departments for the posts and the telegraphs, and he was rather sorry that in India they had amalgamated the two services; it would have been much better, he thought, to have kept to the separation which formerly existed. Again, they had not the same objection abroad to the technically trained man being appointed to the chief administrative post in a department, as was the case in British Government services. For instance, in 1912, in Holland he found that the Director-General of the Posts and Telegraphs was an officer of the Dutch Royal Engineers; in Norway, the Director-General of the Telegraph Department was an officer of the Norwegian Royal Engineers; again, in Bavaria, the Director-General of the Posts and Telegraphs was a civil engineer; in other cases, also, the head of the department was a technically trained man. In the interests of the telegraph service he was sure it was the proper plan to have the technical man as high up as possible in the organisation. While disclaiming an attitude of criticism, he would like to refer to what Mr. Clarke had said about the Baudot system. The Baudot was about fifty years old. It had been immensely improved since its invention, and a great many of the improvements in the Baudot had been made by Mr. Donald Murray, to whom some credit might have been given in the paper. Baudot working was very flexible indeed. If the machine had six "arms," five messages could be sent simultaneously on a single wire in one direction, and one in the opposite, or four in one direction and two in the opposite, and so on. They had gone far in developing the Baudot in America, where the distances were somewhat comparable with those in India. There they were working the Baudot in some cases over distances of 3,300 miles, *e.g.*, New York and Seattle, New York and San Francisco, and New York and Los Angeles. They were not trying at present to get a very large number of channels on a single wire, but were working up their speeds. On the very long lines of 3,300 miles, they were working double-duplex, *i.e.*, two channels simultaneously in each direction or four channels in all, and their speed over that great distance was greater than in India. They got 50 words a minute on each channel, *i.e.*, a total of 200 words a minute on each of the long distance wires referred to. Just as good results were possible in India as in America. In this country conditions, of course, were different; the distances were shorter. The *Scotsman* newspaper had a line from Edinburgh to London, a distance of 400 miles, on which the quintuple-duplex, working at 50 to 60 words a minute per channel, was employed—a maximum of ten messages simultaneously on the one wire, which could carry a total of 500 to 600 words a minute. He believed that on the shorter distance between London and Birmingham, 100 miles, the Post Office had installed a sextuple duplex, *i.e.*, six channels in each direction; or a maximum of twelve channels on a single wire. But there again it was not possible to work at the high speeds mentioned in the old fashioned way with manual keyboards; it was necessary, in order to obtain the speeds mentioned, to have mechanical transmitters and to use tape transmission. Some 2,500 of these mechanical transmitters were to-day in use in the U.S.A.

The Chairman (Lord Montagu of Beaulieu) said that every one must have been struck, not only by the deep interest of the facts contained in the paper, but also by the imagination which Mr. Clarke had displayed in their presentation and his conception of the duties of the officer in India. The discussion had elicited some very interesting speeches. Colonel

Edwards was certainly encouraging in what he had said about the possibility of extension of the air services in the East. Knowing, as he did, something about the climate and the other conditions, he could endorse what Colonel Edwards had told them about the possibilities of the air service in India. He wished to thank the reader of the paper for his kind reference to himself, and the efforts which he had made in getting the Government of India to sanction postal mail services by motor car. He remembered buying six cars in Colombo on his own responsibility; fortunately for himself, the transaction was approved, and the expenditure allowed. It had struck him that more use might be made of motor services in some directions. In many cases in the remoter parts of India speed was not the governing consideration that it was at home. Speed was very important to us here. The life-blood of our commerce was the rapidity and certainty of communication by telegraph, telephone, and post. The man posting a letter in London must be reasonably sure that its intended recipient at Glasgow would get it on the following morning. But in the remoter villages of India, twenty-four hours' delay was not a very important consideration, although it was, of course, a matter of honour for the Post Office to attain the maximum rapidity. He was very glad to have the opportunity of tendering his thanks to the reader of the paper for the charming way in which he had presented his subject. Considering the difficulties which Mr. Clarke had had to contend with in war years, and the subsequent necessity for retrenchment, with the action of the "Geddes Axe" in India, he thought he had done extremely well in his department. His own personal experience while in India was that the Indian Post Office was singularly efficient. He wished to add that Sir William Joynson-Hicks, the Postmaster-General, had sent a message stating that he was very sorry that an engagement in the country prevented him from being present.

Mr. Clarke, replying on the discussion, said that reference had been made by Sir Arthur Fanshawe to certain newspaper reports impugning the reliability of the service. There had been a certain amount of thieving in two or three cities in Central India. It was extraordinary what an amount of harm could be done to the Post Office by one dishonest postman. If he had two thousand letters a day to deliver, and held back only a proportion of them, it would lead to widespread complaint, and the matter would be taken up in the newspapers, which, in India, were not always well off for "copy," and often needed a startling headline. The particular thieves in this instance were caught, and the complaints had now practically ceased. With regard to the technical side of the Telegraph Department, he admitted that his technical knowledge of telegraph work was very limited indeed, and he had only referred quite incidentally to the technical questions involved in the Baudot working. He was well aware that the Baudot system had been developed enormously. The question of the *carrière ouverte* had come forward in the discussion. This matter of the *carrière ouverte* did not mean that they did not intend in India to recruit highly educated engineers, because they did, and always would, and they recruited the best they could get by means of a selection board in London. These men formed the backbone of the engineering and technical staff. But they did open a certain number of appointments to brilliant men in their own ranks who showed uncommon capacity. It was important to have openings for a career for these very brilliant men who were found among the subordinate staff on the traffic side. The question of the rapidity of the services in India was, as Lord Montagu had pointed out, governed by commercial considerations, but the Indian merchant was just as much alive to the need for rapidity as the English merchant; indeed, he was insisting upon rapidity of communications, and more and more in India the service was expected to keep pace with modern developments in communication. The Post Office was out to give the quickest possible service. It was very important that business letters should be delivered early in the morning, and that in the matter of communications the Post Office should be absolutely up-to-date. With regard to the air services India offered an enormous field, and he thought that the time would come before long when what was judged at present to be rather a speculative thing and hedged about by many difficulties would be quite a regular means of transit. The Government and the companies were afraid to make subsidies, but if they would be content to face a preliminary loss, he believed that loss would soon be wiped out. If there was a service from Karachi to Rangoon its value would not be limited to India. Services would come in from England on the one side and from the Dutch Indies on the other.

Sir Michael O'Dwyer, G.C.I.E., K.C.S.I., moved a vote of thanks to Mr. Clarke for his paper, and to Lord Montagu of Beaulieu for presiding. The paper had been most valuable and interesting. His experience of India was that there was no department of the Government more popular or beneficent in its activities than the Post Office. That was the case both in peace and in war, and he saw some admirable illustrations of it. In the Punjab during the War, when half a million of the people were in the army, there was great anxiety among the population as to what was happening at the front, and this was only allayed by the letters received promptly and regularly from the men on service. He remembered one letter

on account of its quaintness. It was sent by a man in France to his relatives in India at the time when the small British Army of "contemptibles" was being nearly wiped out, and it stated that "nearly all the white pepper has disappeared and most of the brown pepper (Indian troops) is gone too." Another way in which the Indian Post Office did good service during the War was in the rapid and effective transmission of remittances from men in the army to their homes. These were distributed quickly and punctually, and the total sums were very large, amounting to some £2,000,000 or more a year. He entirely agreed with Mr. Clarke and other speakers that India could not afford to dispense with a single means of communication. He would like to give an illustration of the value of such supplementary services as wireless. One fine morning in April, 1919, he found himself faced with a very disturbed state of affairs, in fact open rebellion in parts of the Central Punjab. Prompt and drastic action had to be taken in consultation with the Government of India. The telegraph and telephone wires were cut, trains were being derailed, a general railway and telegraph strike was threatened. But there was a military wireless station at Lahore, and he was able to send a message by wireless from Lahore to Simla. This saved a critical situation, but he had not taken the trouble to code the message, and he was reminded from the British agent at Meshed that the message had been picked up by the Bolshevists in Tashkent, and that it was well that uncoded messages reporting a disturbed state of the country should not be broadcasted. The value and effectiveness of the postal and telegraph services in India were due to the fact that they had been under the control of a succession of most efficient administrators--Sir A. Fanshawe, Sir C. Stewart-Wilson and Sir W. Maxwell —who held office for long periods and had succeeded to a marked extent in winning the confidence of their subordinates. That fine tradition was being admirably maintained by Mr. Geoffrey Clarke.

Mr. H. M. Kisch, C.S.I., seconded the motion, and said that his own recollection of India embraced Mr. Clarke's advent to the Post Office. It was, therefore, the greatest pleasure to him to hear Mr. Clarke's story of the work that had been done recently in his department. For the rapid development of communication in India the combination of the Post and Telegraph Offices was almost a necessity. In small countries it might be possible to have the two departments separated, and yet not diminish the efficiency of either, but in a country like India, with its enormous area, it was an immense economy to put the Telegraph Office with the Post Office, and thus enormously to increase the means of communication. His most abiding memory of the Post Office of India related to the loyalty, devotion and honesty of a staff running into many tens of thousands. During the whole time in which he was concerned with the distribution of quinine through the agency of the Post Office, he could not remember a single case in which a packet of the article had been tampered with, and something different substituted. Another illustration of the honesty of the staff was the transmission to their proper destination of thousands of money orders sent by the poorest coolies from distant places where they had gone to work. The addresses often were of the vaguest kind, but the Post Office could be depended on either to deliver the money or to return it to the sender.

The motion having been acknowledged by Lord Montagu of Beaulieu on behalf of himself and Mr. Clarke, the meeting separated.

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Mr. Ashley C. Vernieux writes :—

As I had no opportunity on the occasion of Mr. Geoffrey Clarke's paper to remind him that the Post Office of India has functioned on field service from Flanders to far off Cathay, and at a record altitude when it worked right into Lhasa with the Tibet Expedition in 1904, nor to meet the controversial point which was somewhat unexpectedly raised by Lieut.-Colonel O'Meara, I trust you will be able to afford space for this brief letter.

According to my recollection, Lieut.-Colonel O'Meara commenced with a reminiscence of Burma, referred to Coopers Hill, passed thence to the Continent, and, ignoring the position in England, arrived at the conclusion that the head of an amalgamated service of Posts and Telegraphs should be an engineer. The proposition has never been that an engineering qualification is a handicap or that a good engineer makes a bad administrator. There are brilliant examples to the contrary; but the question is not one of personal attributes. It is rather one which is broad based on principle. Public administration is essentially the work of the civil servant all the world over, whereas the sphere of the technicist is a distinct and well defined one. It seems certain that we should not have had either the original or present day Baudot but for sustained and whole-time attention to the problems which these instruments have solved. The point was shortly stated by an Indian Officer of Telegraphs, who once said to me *à propos* of something else : "I am an engineer; these files are not my work."

GENERAL NOTES.

Victoria and Albert Museum.—The Victoria and Albert Museum has recently acquired through the generosity of the National Art Collections Fund, six roundels of stained glass from a series representing the labours of

the months. These roundels were formerly at Cassiobury Park, Hertfordshire, and are rare examples of English domestic glass, dating from the first half of the 15th century; they are painted in brown enamel and silver yellow stain, and are remarkable for the vigour of their execution. Other recent acquisitions of stained glass include two Dutch panels of the Haarlem school, dating from the early 16th century, purchased out of the income from the bequest of Capt. H. B. Murray.

PRESERVATION OF STONEWORK.—The question of the deterioration of stonework in buildings is a matter of general economic importance, but in the case of our historic buildings and ancient monuments prevention of the serious decay and gradual demolition of tooled surfaces and main structures constitutes a special problem which has engaged attention of many investigators for a considerable time without, however, finding any generally satisfactory solution. The investigation involved is very complex and must be approached from different angles with the help of wide scientific knowledge. Accordingly, it has been decided to set up under the Department of Scientific and Industrial Research a special committee of the Building Research Board to report on the best methods by which decay in building stones, especially in ancient structures, may be prevented or arrested. The Chairman of the Committee will be Sir Aston Webb, K.C.V.O., P.R.A., and the other members will be Mr. R. J. Allison, C.B.E., F.R.I.B.A., Professor C. H. Desch, F.R.S., Mr. A. W. Heasman, O.B.E., Mr. J. A. Howe, O.B.E., Sir Herbert Jackson, K.B.E., F.R.S., Dr. Alexander Scott, F.R.S., Mr. H. O. Weller, M.I.C.E., Hon. A.R.I.B.A. All communications should be addressed to the Secretary, Department of Scientific and Industrial Research, 16, Old Queen Street, S.W. 1.

ART AT THE BRITISH EMPIRE EXHIBITION.—Arrangements are in hand with a view to securing adequate representation of the art of the Empire at Wembley Park in 1924. The Exhibition Authorities have the assistance of an Arts Council upon which the principal Art Societies and all schools of artistic endeavour are represented, under the Chairmanship of Sir Aston Webb, K.C.V.O., C.B., P.R.A. A special Committee for Sculpture is being set up in conjunction with the Royal Society of British Sculptors to secure the finest sculpture of the moment for the adornment, not only of the Art Palace but also of the formal gardens and other parts of the Exhibition Grounds. The Art section as a whole comes within the province of the Director of United Kingdom Exhibits—Sir Lawrence Weaver, K.B.E., and the following officials have been appointed—Assistant Director, Fine Art, Mr. Alfred Yockney; Assistant Director, Applied Art, Major A. A. Longden, D.S.O.; Secretary to the Arts Council and the various Committees, Mr. H. W. Maxwell. The Art Section is located at the General Exhibition Offices at 16, Grosvenor Gardens, London, S.W. 1. An Art Palace is in course of erection, which will provide over 40,000 superficial feet of floor space, divided into numerous Galleries affording facilities for the display of a large art collection under the most favourable conditions.

INLAND WATER ROUTE FROM GERMANY TO PERSIA.—During the latter part of July, 1922, a Hamburg shipping company dispatched a specially constructed steamer of 200 gross tons from Hamburg to Enzeli, Persia, in order to ascertain the practicability of establishing a regular freight service between Germany and the Near East *via* Russian Waterways. The vessel with a cargo of sugar, sewing-machines, bicycles, underwear, and shoes, passed through the North Sea, the Baltic Sea, the Gulf of Finland, the St. Mary Canal system (which connects the Gulf of Finland with the Volga, through Lake Ladoga), down the Volga, and through the Caspian Sea to Enzeli. The vessel is to remain at Enzeli until ice conditions on the Russian waterways permit its return to Hamburg with a cargo of native merchandise. In view of the apparent success of this expedition, writes the United States Commercial Attaché at Berlin, the company is planning to enlarge and extend its services, and has placed orders for several ships of a type suited to this route.

EXPANSION OF FUR FARMING IN CANADA.—Fur-bearing animals on fur farms in the Dominion of Canada on December 31, 1921, numbered 22,455, valued at $5,775,095, compared with 16,529 animals valued at $4,722,905, on the same day in 1920. Of these animals the silver fox, patch fox, and red fox constituted 19,025 of the total number of 1921. The maritime provinces as a whole lead in the fur-farming industry, writes the United States Consul General at Halifax, Nova Scotia, Prince Edward Island standing first in importance of all the Provinces in regard to number and value of fur farms and fur-bearing animals. The island in 1921 had 359 fox farms, valued at $737,085, with fur-bearing animals valued at $3,248,120.

SUGAR BEET CROPS IN 1922.—According to data furnished by the International Institute of Agriculture, the yield of sugar beet in Europe during 1922 was somewhat greater than the very poor crop of 1921, but considerably (about 24%) below the average from 1909 to 1913. The slight increase of American production in 1922 as compared with the pre-war total does not counterbalance the great decrease in Europe, and consequently the world's yield (35 million metric tons) is less by 24% than the average from 1909 to 1913 (45 millions) and very little

larger (4%) than that of 1921 (34 millions), a most deficient out-turn. The decrease in the 1922 production as compared with pre-war figures originates with the reduction of area sown in Europe and is intensified by deficient yields per acre both in Europe and America. As compared with an average yield per acre of 26 metric tons from 1909 to 1913, the out-turn in 1922 was only 24.3 tons. The data just mentioned do not include those of present day Russia, where rough estimates make the production less than 20% of the pre-war average for the same territory; the pre-war yield was about 9.5 million tons.

MEETINGS OF THE SOCIETY.

Dominions and Colonies Section.

Tuesday, June 5th, at 4.30 p.m.—Sir Edward Davson (President of the Associated West Indian Chambers of Commerce; Chairman of the British Empire Sugar Research Association, Vice-President of the British Empire Producers' Organisation), "The Economic Conference and Crown Colony Development." His Grace the Duke of Devonshire, K.G., G.C.M.G., G.C.V.O., P.C., Secretary of State for the Colonies, will preside.

Indian Section.

Friday afternoons.

June 15, at 4.30 p.m.—Sir John H. Marshall, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture.) The Most Honourable The Marquess Curzon of Kedleston, K.G., G.C.S.I., G.C.I.E., P.C., F.R.S., will preside.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

Monday, June 4..University of London, University College, Gower Street, W.C., 5 p.m. Prof. H. A. Lorentz, "Problems in Relativity." (Lecture I.)
At King's College, Strand, W.C., 5.30 p.m. Prof. R. Dyboski, "Outlines of Polish History." (Lecture VI.)
Royal Institution, Albemarle Street, W., 5 p.m. General Meeting.
Geographical Society, 135, New Bond Street, W., 8.30 p.m. Mr. F. Rodd, "Journeys in Air."
Chemical Industry, at the Chemical Society, Burlington House, Piccadilly, W., 8 p.m. Prof. H. S. Hele-Shaw, "The Stream-Line Filter."
Actuaries, Institute of, Staple Inn Hall, W.C., Annual General Meeting, 5 p.m.

Tuesday, June 5..University of London, University College, Gower Street, W.C., 5 p.m. Prof. H. A. Lorentz, "Problems in Relativity." (Lecture II.)
At King's College, Strand, W.C., 5.30 p.m. Miss Hilda D. Oakley, "The Conflict within the Greek Moral Ideal." (Lecture I.)
Royal Institution, Albemarle Street, W., 3 p.m. Prof. Flinders Petrie, "Discoveries in Egypt." (Lecture III.)

Wednesday, June 6..University of London, University College, Gower Street, W.C., 6.15 p.m. Sir Josiah Stamp, "Economical and Statistical Aspects of a Capital Levy." (Lecture III.)
5 p.m. Prof. G. N. Lewis, "The Structure and Behaviour of the Molecule." (Lecture I.)
At the School of Oriental Studies, Finsbury Circus, E.C., 5 p.m. Dr. P. Giles, "The Argans." (Lecture III.)
British Academy, at the Royal Society, Burlington House, Piccadilly, W., 5 p.m. Prof. W. R. Scott, "Adam Smith."
Geological Society, Burlington House, Piccadilly, W., 5.30 p.m.
Archæological Institute, at the Society of Antiquaries, Burlington House, Piccadilly, W. at 5 p.m. Mr. Arthur Gardner, "Alabaster Tombs."
Electrical Engineers, Institution of (Wireless Section), Savoy Place, Victoria Embankment, S.W., 6 p.m. Mr. C. E. Horton "Wireless Direction—Finding in Steel Ships."

Thursday, June 7..Labour Co-partnership Association, Congress at the Royal Society of Arts, John Street, Adelphi, W.C., 10.30 a.m. Mr. C. G. Renold, "The Place of the Worker in Industry."
2.45 p.m. Miss Dorothy Cadbury, "Women in Industry."
University of London, University College, Gower Street, W.C., 5 p.m. Prof. H. A. Lorentz, "Problems in Relativity." Lecture III.)
5.15 p.m. Prof. J. E. G. Montmorency, "Customary French Law." (Lecture V.)
Royal Institution, Albemarle Street, W., 3 p.m. Sir W. M. Bayliss, "The Nature of Enzyme Action." (Lecture II.)
Linnean Society, Burlington House, Piccadilly, W., 5 p.m.
Chemical Society, Burlington House, Piccadilly, W., 8 p.m. (1) Mr. H. Hunter, "Investigations on the dependence of Rotary Power on Chemical Constitution. Part XX. The Rational Study of Optical Properties: Refraction a Constitutive Property." (2) Mr. A. E. Goddard, "Researches on Indium. Part I. Diphenyl Indium Chloride and Phenyl Indium Oxide." (3) Messrs. E. P. Perman and W. J. Howells, "The Properties of Ammonia Nitrate. Part VI. The reciprocal Salt Pair, Ammonia Nitrate and Potassium Sulphate." (4) Messrs. E. W. Lanfear and J. F. Thorpe, "Ring Chain Tautomerism. Part VI. The Mechanism of the Keto-Cyclol Change in the Propane Series." (5) Mr. E. H. Usherwood, "The Reversibility of Additive Reactions. Part I. The Aldol Reaction." (6) Mr. C. K. Ingold, "Mechanism of the Pinacone-pinacoline and Wagner-Merrwein Transformations." (7) Mr. A. E. Goddard, "Researches on Antimony. Part I. Tri-mo-xylylstibine and its Derivatives."

Friday, June 8..Labour Co-partnership Association Congress, at the Royal Society of Arts, John Street, Adelphi, W.C., 10.30 a.m. Mr. J. A. Bowie, "Contributory Co-partnership through Investment."
2.30 p.m. Discussion on "Modern Types of Co-partnership."
University of London, University College, Gower Street, W.C., 5 p.m. Prof. G. N. Lewis, "The Structure and Behaviour of the Molecule." (Lecture II.)
King's College, Strand, W.C., 5.30 p.m. (Shakespeare Association.) Mr. Allardyce, "The Editors of Shakespeare from First Folio to Malone."
Royal Institution, Albemarle Street, W., 9 p.m. Miss Joan Evans, "Jewels of the Renaissance."
Astronomical Society, Burlington House, Piccadilly, W., 5 p.m.
Malacological Society, at the Linnean Society, Burlington House, Piccadilly, W., 6 p.m.
Physical Society, Imperial College of Science, South Kensington, S.W., 5 p.m.

Saturday, June 9..Royal Institution, Albemarle Street, W., 3 p.m. Dr. A. W. Hill, "The New Zealand Flora"

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***All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.* (2)**

NOTICES.

NEXT WEEK.

FRIDAY, JUNE 15th, at 4.30 p.m. (Indian Section.) SIR JOHN H. MARSHALL, C.I.E., M.A., Litt.D., F.S.A., Director-General of Archæology in India, "The Influence of Race on Early Indian Art." (Sir George Birdwood Memorial Lecture.) THE MOST HONOURABLE THE MARQUESS CURZON OF KEDLESTON, K.G., G.C.S.I., P.C., F.R.S., will preside.

TWENTY-FIRST ORDINARY MEETING.

WEDNESDAY, MAY 30th, 1923; MR. L. BERESFORD SEYLER in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Allen, James Key, F.R.H.S., Chatham, Kent.
Branscombe, Charles W., London.
Derrick, E., London.
Good, Prof. John W., Ph.D., Georgia, U.S.A.
Gupta, Sudhansu Mohon, M.B., Assam, India.
Holbrook, Colonel Sir Arthur, K.B.E., M.P., London.
Khan, K. Inayatullah, M.A., Peshawar, India.
Leach, Frank L., Tatanagar, India.
Searson, James W., Nebraska, U.S.A.
Smith, John D., London.

The following candidates were duly elected Fellows of the Society:—

Banerjee, Satya Kishore, M.A., B.L., Calcutta.
Cannings, Reginald Edward, Bath.
Herbert, Charles Edward, London.
Jepson, Willis Linn, Ph.D., California, U.S.A.
Keiller, Fred G., London.
Kinloch, John, Mergui, Burma.
Larrouy, Francis Isidore, Demerara, British Guiana.
Zollikofer, R. V., Rangoon, Burma.

A paper on "The History and Development of Children's and Invalids' Carriages" was read by Mr. Samuel J. Sewell.

The paper and duscussion will be published in a subsequent number of the *Journal.*

INDIAN SECTION.

FRIDAY, JUNE 1st, 1923; SIR CHARLES C. MCLEOD, Member, Board of the British Empire Exhibition, in the Chair.

A paper on "The Participation of India and Burma in the British Empire Exhibition, 1924," was read by MR. AUSTIN KENDALL, I.C.S., retd.

The paper and discussion will be published in a subsequent number of the *Journal.*

DOMINIONS AND COLONIES SECTION.

TUESDAY, JUNE 5th, 1923; HIS GRACE THE DUKE OF DEVONSHIRE, K.G., G.C.M.G., G.C.V.O., P.C., Secretary of State for the Colonies, in the Chair.

A paper on "The Economic Conference and the Colonies" was read by SIR EDWARD DAVSON.

The paper and discussion will be published in a subsequent number of the *Journal.*

PROCEEDINGS OF THE SOCIETY.

SEVENTEENTH ORDINARY MEETING.

11TH APRIL, 1923.

CAPTAIN BERTRAM BROOKE, Tuan Muda of Sarawak, in the Chair.

THE CHAIRMAN, in opening the meeting, said that Sarawak had previously formed the subject of lectures in England, a notably interesting discussion of its history and government being given by Dr. Charles Hose in a paper recently read before the Royal Colonial Institute. He thought, however, the present paper was the first time an attempt had been made to examine the status of Sarawak purely with regard to its commercial point of view. The author had had exceptional facilities for collecting and studying the material on which he had based his paper, in that he was for a considerable

time Chief Government Auditor in the Sarawak Civil Service. In the course of his duties he had to make what practically came to an annual tour throughout the country, during which he not only audited the books at the headquarters' stations in the various districts, but visited every small Government post, both on the coast and up country, where any sort of check or tally for revenue purposes was kept. Latterly he had resigned his position under Government to take up the Managing Directorship of the Sarawak Steamship Company. He had taken that step at the request of the Chinese merchants, who formed the backbone of the trading community. That new position had given him still further opportunities to increase his knowledge with regard to a subject which was to him somewhat in the nature of a hobby. Unfortunately, Mr. Parnell was still in Sarawak, and, therefore, could not read the paper himself, but he had been extremely fortunate in finding Mr. Collingwood Hughes, M.P., who had very kindly consented to perform that service for him.

Mr. Collingwood Hughes said that they were having rather strenuous times in Parliament, and he did not know whether he would have been able to get away, but there were times when appointments must be kept. His own knowledge of Sarawak had been derived almost exclusively from his perusal and re-perusal of Mr. Parnell's excellent paper, and he was really present as Mr. Parnell's mouthpiece, he might almost say as a gramophone record, and as a record he would try to do a little better than some of the records people were accustomed to.

The paper read was:—

SARAWAK: ITS RESOURCES AND TRADE.

By E. Parnell,
late of the Sarawak Civil Service.

So little is known of Sarawak by the British public, that it is necessary to give a short description of its position in the world, and a sketch of its early history, before we consider its Resources and Trade.

Position.

The territory of Sarawak, comprising an area of about 50,000 square miles with a population of about 600,000, is situated on the N.W. Coast of the Island of Borneo, and commands a coast line of some 400 miles washed by the China Sea.

It contains two rivers, the Rejang and the Sarawak, which are of sufficient size to give entrance to large steamers to carry the foreign trade of the country.

The former is navigable for steamers of 1,500 tons as far as Sibu, 60 miles from the coast, and probably as far as Kapit, 150 miles from the coast. At both of these places there are Government stations, and at the former are the headquarters of the Government for the district. Within 20 miles of the mouth there are situations capable of being made into a shipping port, with soundings up to ten fathoms at the banks of the river. The soundings on the bar at low tide give 15 feet, and the tides rise from 9 to 13 feet.

The Sarawak river is navigable for steamers of 1,500 tons, and 250 feet in length, up to Kuching, the Capital of Sarawak, 23 miles from the mouth. There is, however, a situation at Pending, 11 miles from the mouth, suitable for a port for much larger vessels. The soundings on the bar at low tide give three fathoms, and the tides rise from 5½ to 9 feet.

Of the other large rivers of Sarawak, the following should be noticed:—The Batang Lupar, the Baram, the Bintulu and the Sadong rivers, which, with the exception of the first mentioned, are navigable for small steamers with eight foot draft.

The Sadong river, like the Rejang and Sarawak rivers, is navigable for larger steamers as far as Simunjan, 18 miles from the mouth, where the Government coal mines are situated, but a dangerous bore at full and change for four days with the first of the flood has to be reckoned with.

The Mukah, Oya, Kalakah, Balingean and Tatau rivers are navigable for steamer, of six foot draft only; the two former ares however, of importance, being in the centre of the Sago industry.

In addition to these river ports there is an anchorage off Miri which, though extremely dangerous in rough weather, especially during the N.E. Monsoon, serves as the shipping port for the Oil Company, where oil tankers are fed by a pipe line three miles out to sea.

As regards the position of Sarawak in reference to trade, the following figures may be of interest:—

Sarawak to Singapore	450	miles.
Sarawak to Manila	1050	miles.
Sarawak to Saigon	630	miles.
Sarawak to Hongkong	1380	miles.
Sarawak to Bangkok	1000	miles.
Sarawak to Rangoon	1540	miles.

HISTORY

It is not my intention to give the History of Sarawak in detail—this would form the subject of a lecture in itself. It is necessary, however, to trace the growth of Sarawak under the rule of the Brooke Rajahs.

Sir James Brooke, the first Rajah, arrived in Borneo in 1839; he was offered the State of Sarawak then extending from Cape Datu to the Sarawak river in 1840, and was proclaimed Rajah in Brunei in 1842. He died in 1868. During his rule concessions were obtained for the coast from Sadong to Oya in 1846, the upper Rejang river in 1856, the Mukah river in 1857, and the coast to Bintulu in 1861. Thus the State of Sarawak was increased from a district with an area of about 3,000 square miles, and a coast line of about 60 miles to a country with an area of about 35,000 square miles and a coast line of about 250 miles.

Sir James Brooke was succeeded by his nephew, Sir Charles Brooke, who obtained concessions for the coast from Bintulu to Baram in 1883, the Trusan river in 1885, and Lawas in 1905, while Limbang was annexed in 1890. Thus he became the ruler of the whole of the N. W. Borneo from Tanjong Datu to Lawas, lying eastwards of Labuan Island, with the exception of the territory of Brunei, which has an area of about 4,000 square miles.

In 1888 Sarawak was placed under British protection as regards its foreign affairs, the British Government undertaking not to interfere with the internal administration of the state.

Meanwhile, in 1883 the British North Borneo Company received a Charter from Great Britain and took over the Northern part of Borneo with an area of some 30,000 square miles. The Sultans of Brunei were thus left with the district surrounding their capital as the remains of a country, described by an anonymous writer in "More's Indian Archipelago," published in 1837, as "one of the most considerable Kingdoms in Asia," known as Borneo Proper.

We now come to the object of this paper, namely, an enquiry into the Resources and Trade of Sarawak.

To trace its early trade before the arrival of Sir James Brooke, we find it necessary to consider the resources and trade of Borneo Proper.

The writings of adventurers of the eighteenth and nineteenth centuries have been consulted, and whilst several notes of great interest have been found, the information concerning Borneo, apart from Brunei is very meagre; this is not surprising when it is considered that the whole district was torn with internal strife, and the coast unapproachable owing to the activity of pirates of the most savage description.

EARLY TRADE AND RESOURCES OF BORNEO PROPER.

Captain Thomas Forrest, writing in 1779, describes the trade of Brunei, which port he visited in 1776, as follows:—

"Great quantities of Blackwood . . "bought for about 2 dollars a picul and "sold for 5 or 6 are exported, also ratans; "damar, a kind of resin; clove bark; "swallo; tortoishell; birds nests, etc......, "the best kind of native camphor is exported "hence . . . it looks no better (than "Sumatra 'camphire') but is much dearer, "selling for ten or twelve Spanish dollars "the Chinese catty."

An anonymous writer in "More's Indian Archipelago," writing in about 1820 to 1830, says: "Borneo contains a number "of fine rivers which, in a more advanced "state of civilisation than any of its inhab- "itants have yet attained, might be turned "to commercial and agricultural advantage. "The most important are the rivers of "Rayung[1] and Balawi[2] which lead to "Sibatu,[3] the Capital of Kayan. . . . "The districts further to the west on the "other hand, such as Sarawak and Kalaka "between the second and third degrees of "N. latitude, abound in metals such as gold, "antimony and zinc. In the country of "the Kayan, tin and iron exist, the latter "rich enough to be wrought to a considerable "extent even by the barbarian inhabitants "of the country." . . . . "The remarkable or useful productions "of the principality of Borneo may be "enumerated as follows:—In the mineral "kingdom, besides the productions already "mentioned, there exist diamonds . . . "The seas afford the tortoise, the pearl "oyster. . . . The productions of "nature, valued for their utility or singu- "larity, are rice, sago, black pepper, "camphor, cinnamon, beeswax and useful "or ornamental woods." At the end of his article on Borneo he says:—

1 Rejang.
2 Balleh.
3 Probably Mt. Batu.

"Its trade is the most important con- "sideration respecting Borneo, and deserves "to be considered at more length than the "topics we have just glanced at. An "important fact ought to be adverted "to, that the river of Borneo is the only "port of the Indian Archipelago where "the Chinese have found it practicable and "convenient to construct huge junks. A "junk of 580 tons burthen laid in the "beginning of March was launched at the "end of May. Her whole cost aud outfit, "although artificers and iron work were "brought from China, did not exceed "4,250 Spanish dollars or about 30 shillings "sterling the ton, an example of cheap "ship-building quite without parallel in "any other country."

Hunt, writing in 1812, says:—

"About 1° north of Sambas is a country "called Sarawan[4] belonging to the Rajah "of Borneo Proper, there is a vast district "abounding in tin, in veins as rich and as "plentiful as those wrought on Banca; "but they have been neglected for a series "of years, they were partially wrought "before those of the latter were discovered, "in the beginning of the last century." In the same article he says:

"The town of Calaca[5] belonging to the "Rajah of Borneo Proper lies N. of Tanjong "Datu, it is the principal port of trade "south of the Capital, and the mart of the "Sedang[6] country, here much grain is pro- "duced, 100 piculs of black birds nests, "200 piculs of wax, some gold, pepper, "camphor, etc., but the tin mines, before "mentioned, are utterly neglected."

Crawfurd,[7] writing in 1856, says:

"The geographical formation (of Sarawak) "consists of sandstone granite, but possesses "neither the gold of the southern districts "of the island, nor the coal of the northern, "its only discovered mineral hitherto being "antimony. . . . In 1854, its exports "are stated to have amounted to the value "of 1,000,000 Spanish dollars, and its "imports to 800,000."

Under the heading "Tin," this writer says:

"The ore would seem only to become the "more abundant as it approaches its "termination at Banca and Billiton. The "localities richest in tin are ascertained to "be those near the junction of sandstone "with granite, and all the countries rich "in tin are observed to be so in iron."

Mentioning that Mr. Dalton, who visited the Kayans in 1828, discovered iron ore on the northern side of the equator, and that the discovery of a similar iron ore is described by "an anonymous but very judicious traveller" in Matan,[8] Crawfurd says:

"It will be found when subjected to "scientific analysis, a magnetic oxide, such "as yields the best iron and steel of Sweden ". . . . . most of the iron and steel "manufactured in Asiatic countries by "civilised nations . . . . . is not "above one half of the value of English "iron and steel, while that of the wild "Dyaks is by near 20 to 25% superior to "them."

Under the heading "Copper," Crawfurd says:—

"Ores of this metal have been found in "Sumatra, Celebes and Timur, and most "probably in time will be found in "'Borneo.'"

To summarise the known resources of Borneo Proper up to the arrival of Sir James Brooke they are as follows:—

Antimony, the chief source of supply for the world.

Diamonds, mentioned as one of the products.

Iron, of very fine quality known to exist and to be wrought by Kayans and Dyaks.

Tin, a large field known to have been worked in the 18th century, but latterly neglected.

Timber, suitable for boat building, plentiful and cheap.

Coal, stated by Crawfurd not to exist in Sarawak.

Gold, stated by Crawfurd not to exist in Sarawak, but known to be exported from Brunei.

Copper, its presence was assumed to be probable.

Produce, the following products known:—

Rice, birdsnests, beeswax, pepper, camphor, damar, tortoiseshell and ratans. Sago also was one of the staple foods of people living on the coast.

4 Sarawak.
5 Kalaka.
6 Sadong.
7 Crawfurd never visited Borneo Proper, so his writings are more valuable for their quotations than as a reliable description of the country—for an example of his ignorance see his statement about Coal and Gold.

8 About 1° South of the Equator.

TRADE UNDER THE BROOKE RAJAHS.

We will now enquire into the result of the Rajahs' rule with regard to trade. I propose in the first place to deal with total trade and later to consider the development of the resources already mentioned and encouragement given to general trade. For the object at which we are aiming it is necessary to consider tables of statistics. This table shows the advance made in quantities and values of trade, in the earlier years giving details as far as they can be traced and later in decennial periods.

2. Encouragement given to a company to plant sugar cane.

3. Direct encouragement to planters of pepper and gambier.

4. The working of Sadong Coal Mine by the Government.

5. Experimental planting of tea, coffee and tobacco.

6. The importation of Chinese to plant rice in the Rejang River.

7. Grants of land for rubber planting.

8. A concession for working Jelutong.

9. A concession of oil rights.

SARAWAK.

Comparison of Foreign Imports and Exports, 1842-1920.

Imports.			Exports.		
Year.	Tons.	Value.	Year.	Tons.	Value.
		$			$
1842		(figures not obtainable.)			60,000.—
1854	10,476	319,639.—	1854	11,512	352,195.—
1863	21,720	1,155,201.—	1864	22,133	1,222,443.—
1870	9,560	1,494,241.—	1870	8,728	1,328,963.—
1880	14,653	1,091,300.—	1880	15,565	1,193,195.—
1890	34,751	1,477,893.—	1890	36,861	1,700,142.—
ff1900	22,062	3,848,679.—	1900	23,205	*5,217,036.—
1910	59,796	752,533.—	1910	61,674	†8,152,293.—
1920	173,773	14,680,520.—	1920	136,453	‡18,067,121.—

An analysis of these figures will show that after 1890, by which date the Rajah had consolidated his kingdom, attention was turned to the development of the resources and trade of the country with a resulting increase of volume and values of remarkable rapidity.

The Government was directly responsible for this increase, not only in so far as it was due to settlement of disorders and the founding of a stable government, but also by direct encouragement of certain industries.

From the *Sarawak Gazette*, the semi-official publication of the Government in early days, I have obtained the following particulars of direct encouragement from the Government:—

1. A concession to the Borneo Company, Limited, to exploit mineral resources of the whole country.

ff. In 1900 there was a decrease of exports of Coal of 11,000 tons; it is curious that there is no explanation of the large decrease in imports in the Register of Trade's Report.

* Export of Gold valued at $843,709 as against $16,599 in 1890.

† Export Jelutong valued at $3,000,000 as against $2,262 in 1900.

‡ Export Oil valued at $6,690,000 as against Nil in 1910.

10. Assistance to natives during the rice crisis.

In some cases these experiments were a failure, notably the plantation of tea, coffee and tobacco and the importation of Chinese to plant rice. The sugar plantation failed through the selection of poor soil and bad management.

The late Baroness Burdett-Coutts took a great interest in the encouragement of agriculture and owned an experimental plantation of some two hundred acres, wherein amongst other things the soap palm was planted on a large scale. The garden is now abandoned.

The success of the other schemes will be noted when discussing trade in detail.

AGRICULTURE.

It seems natural to consider agriculture first, not because it provides the largest proportion of trade, but because it is in this direction that the inhabitants of the country should devote their energies.

Separating the value of agricultural exports from the trade returns we find that the exports of agricultural and jungle produce were:—

EXPORTS OF AGRICULTURAL AND JUNGLE PRODUCE.

Year.	Value.
	$
1876	634,000
1886	922,000
1896	1,937,000
1906	5,133,500
1916	7,286,500

4. All agreements between planter and coolies to be registered in the Courts.

5. Penalties instituted for non-delivery of produce by coolies working under advances to planters.

6. No export duty on pepper or gambier for four years.

7. No import duty on provisions for coolies for six years.

The following table will show the resulting increase in production of these commodities:

EXPORTS OF GAMBIER AND PEPPER.

	Gambier.		Pepper.	
Year.	Quantity.	Value.	Quantity.	Value.
	Tons.	$	Tons.	$
1877	6	686.—	2	358.—
1880	1,491	97,852.—	21	3,850.—
1885	1,381	121,367.—	395	121,997.—
1890	1,170	133,235.—	1,009	237,476.—
1895	1,323	210,433.—	922	240,248.—
1900	2,197	200,609.—	2,397	1,254,422.—
1905	1,203	155,015.—	4,474	2,638,414.—
1910	891	134,149.—	3,684	1,531,246.—
1915	622	93,955.—	2,754	1,390,188.—
1920	97	13,954.—	1,082	712,122.—

We noted that the Government had given direct encouragement to pepper and gambier planters. I propose to give the terms of the proclamation published in 1876 and to consider the results of this encouragement.

The most important clauses in the Proclamation were :—

1. Grants of land for 99 years; subject to bona fide cultivation.

2. Free passages to planters and coolies from Singapore.

3. The appointment of Kantchew (Chinese headmen) with certain powers of control, including settlement of cases of minor offences.

In 1880 a survey of gambier and pepper cultivation was made, there were 229 gardens totalling 9,548 acres, employing 1,840 coolies and producing 1,491 tons of gambier, whereas 339,790 pepper vines had been planted.

Pepper being by far the more important of these industries, I propose to discuss the rapid rise and sudden collapse of this industry.

These figures will show to what extent the cultivation of pepper increased up to the "boom year" 1905-6, when exports reached 5,428 tons and then its sudden collapse.

INCREASES OF THE EXPORTS OF PEPPER FROM 1901 TO 1906 AND THEIR SUBSEQUENT DECLINE.

		$
1901	2,221 tons were exported valued at	1,477,499.—
1902	2,845 ,, ,, ,, ,, ,, ...	2,205,762.—
1903	3,361 ,, ,, ,, ,, ,, ...	2,733,301.—
1904	3,817 ,, ,, ,, ,, ,, ...	2,611,478.—
1905	4,474 ,, ,, ,, ,, ,, ...	2,638,414.—
1906	5,428 ,, ,, ,, ,, ,, ...	2,394,278.—
1910	3,684 ,, ,, ,, ,, ,, ...	1,531,246.—
1920	1,082 ,, ,, ,, ,, ,, ...	712,122.—
1921	1,954 ,, ,, ,, ,, ,, ...	827,508.—

When the bubble burst in 1906 many planters were ruined, gardens were consequently abandoned and disease became rife throughout the plantations. The disease of "black berries" is to-day mainly responsible for the rapid decline of exports, it was considered incurable and nothing was done to stop its spread. Recently, however, the F.M.S. Government Mycologist who has inspected the gardens, reports that the disease is curable at reasonable cost, and steps are about to be taken to carry out his recommendations.

When the rubber boom came hundreds of plantations were interplanted to the ruin of the existing vines and incidentally to the detriment of the growth of the rubber trees. Thus we see a flourishing industry, started at great expense to the Government, ruined by over speculation and neglect.

To what extent did the Government try to prevent its collapse? The late Rajah (Sir Charles Brooke) warned his people against planting rubber on land already under cultivation.

It was not surprising that his people took but little notice of this advice when one considers the blind faith of business men throughout the world in the prospects of rubber. When it was seen that rubber planting was undertaken by natives as a speculation only, a tax of 10% on the value of gardens transferred was introduced in the hope that this would act as a deterrent to indiscriminate planting. On the other hand nothing was done to stop the spread of disease; it is surprising that, having fostered the industry to such an extent, the few hundred dollars necessary for scientific research was not expended, when no doubt a cure would have been found. Regulations should have been made to prevent the planting of shoots from diseased vines. Had this been done the new plantations would not have been infected as, unfortunately, is the case at present.

Gambier.—Planters never had the success that pepper planters achieved, and its cultivation has, to a great extent, died out. The causes of its decline are the working of cutch, which dye is cheaper to produce, and also the work on a gambier estate is extremely heavy; when the rubber planting began coolies left the gambier gardens for the rubber estates where work was comparatively light, and to-day it is difficult to obtain coolie labour on a gambier estate.

Although gambier as a dye is superior to cutch, for ordinary purposes the latter is more commonly used. While it would be possible to produce gambier at a price to compete with cutch the difficulty of obtaining labour has disheartened the planters. It would appear that the introduction of machinery for the treatment of gambier leaves might cause a revival of the industry.

Sago. Study of the course of this industry presents a more pleasing picture. Its cultivation and manufacture have gradually increased and its exports form the backbone of Sarawak export trade. In 1870 exports were valued at $128,023, while in 1920, 15,618 tons were exported, valued at $2,297,058; the export increased in quantity in 1921 to 18,096 tons, but the value decreased to $1,455,505. The greatest quantity exported during this period was in 1919, when 23,198 tons, valued at $4,249,770, were shipped.

Jelutong. In 1909 the Government granted certain rights in Sarawak for working Jelutong, this drew the attention of natives to the value of this product of the jungle.

The exports in 1908 were 2,310 tons, value $203,346, increasing in 1909 to 8,766 tons, value $1,025,400.

During this year the company began to "refine" raw jelutong, extracting impurities, including resin and reducing the moisture for export, with the following results.

EXPORTS OF JELUTONG, RAW AND REFINED.

	Raw Jelutong.		Refined Jelutong.	
Year.	Quantity.	Value.	Quantity.	Value.
	Tons.	$	Tons.	$
1910	6,412	1,089,274.—	354	1,855,773.—
1911	3,399	457,841.—	445	1,652,227.—
1912	2,334	313,146.—	—	—
1913	2,814	343,722.—	24	13,637.—
		rising again above the million mark in		
1919	4,538	1,009,095.—	2,007	1,130,518.—
1920	4,333	1,175,136.—	939	829,108.—

The history of the United Malaysian Rubber Company which worked this concession is too fresh in the mind of the business public to require revival here: suffice it to say that had the company continued as first formed they would have undoubtedly met with success. Over capitalisation combined with speculation was its ruin. However, the revival caused in the jelutong industry continues and refining is now done by Chinese traders.

To summarise the increased trade in agriculture, we find a more than 10-fold increase in exports in 40 years; with a total value of trade in pepper of $37,000,000 and in gambier of $6,000,000 due to direct encouragement from the Government.

MINERALS.

It was, wisely, considered that the mineral wealth of the country should be developed by capital from outside—it should be remembered that until very recent years the Government has been severely hampered by lack of capital—thus the sole right of working minerals (other than coal) was conceded to the Borneo Company, Limited, in 1857.

This company has confined its attention mainly to the upper waters of the Sarawak River, where they have had a certain amount of success; it is difficult for one who has no technical knowledge to judge whether this company has made the best of its concession, but it may with fairness be suggested that a more thorough prospecting of the whole country might have brought to light considerably greater mineral resources than has been the case.

The inaccessibility of a country covered with dense jungle to the tops of the mountains is recognised, and, doubtless this causes the prospecting to be confined more or less to the banks of rivers, but when we consider that the writings of travellers, with considerable knowledge of their subjects have shown that tin mines have been worked, iron ore of good quality is wrought by Kayans to this day and traces of gold are known to be present in several rivers, it is surprising that more mineral wealth has not been discovered than that of the head waters of the Sarawak River.

Antimony to the value of $1,905,031 has been exported between the years 1870 and 1916; this has been obtained from Jambusan, Buan, Bidi and Paku, all in the head waters of the Sarawak River.

Quicksilver to the value of $1,159,966 was exported between 1870 and 1899 obtained from Tegora (Upper Sarawak River).

Gold has been exported from the mines at Bau and Bidi (Sarawak River) to the value of $24,825,328 from 1898 to 1921: this mine is now closed down and the machinery has been dismantled.

Coal has been worked by the Government at the Simunjan mines in the Sadong River and also at Brooketon (near Brunei); the object of the Government hitherto has been more to supply local needs than to develop the coal resources of the country, although a considerable quantity has been produced.

Coal fields have been found in most rivers in Sarawak, but particularly at Selantik in the Batang Lupar and on the coast at Bintulu. All these coals are of good steaming quality, at least equal to Japanese coal, and some probably superior.

Copper Ore is mentioned in the Sarawak Gazette for May, 1873, as being found in the Kalakah district.

Oil. In 1909 the Anglo-Saxon Petroleum Co., Ltd., obtained a concession for the whole country, and, after some years of experimental work and prospecting, exported for the first time in 1914, when 45,039 tons, valued at $377,537, were shipped. The export of oil has increased with great rapidity. In 1921 there were shipped 170,272 tons valued at $7,549,140, and in 1922 upwards of 400,000 tons were produced.

The importance of this development is very great, forming, as it does, a bunkering station, sufficient to supply the needs of the British Navy in the East, situated in a State enjoying the protection of Great Britain.

In 1920 a separate company, known as the Sarawak Oilfields, Limited, was formed, which is developing the present fields at Miri and in the Baram River with extraordinary energy; meanwhile, it is prospecting the land on other rivers where traces of oil have been found.

TIMBER.

There is an abundance of available timber throughout the whole of Sarawak, and the following notes are supplied to me by the kindness of the Conservator of Forests, Mr. J. P. Mead.

The Forests of Sarawak may be divided into two classes:

A. Littoral Forests.
B. Inland Forests.

The latter may be subdivided into lowland forests (up to 2,000 feet) and high hill forests (over 2,000 feet). In addition to these there are some thousands of square miles of secondary forests, resulting from the shifting cultivation of the Dyak and other tribes.

A. Littoral Forests.

Mangrove forests cover a very extensive area. A large part of this is found in the delta of the Rejang, smaller areas in the delta of the Sarawak River and in Sarawak territory in Brunei Bay.

Most of the species occurring in the Mangrove swamps belong to the Rhizophoraceæ; these species make excellent firewood and charcoal, cutch is extracted from the bark. The present outturn of firewood and charcoal is about 50,000 tons a year, which could be increased to a permanent output of 500,000 tons a year. Singapore is a good potential market for mangrove charcoal, but at present the export is nil.

About 50,000 acres of littoral forests have been surveyed and constituted reserve forests.

B. Inland Forests.

The high hill forests being quite inaccessible at present and likely to remain so for many years to come, we will discuss the lowland forests only.

In these forests three natural orders furnish the bulk of the best timber, the Dipterocarpaceæ, Leguminosæ and Lauraceæ. It is estimated that Dipterocarpaceæ form about 60% of the growing stock in these forests. The timbers of this family are resinous and sometimes possess an aromatic odour. The order comprises timbers from very light and very soft to very hard and very heavy ones, and in colour from white, yellow, grey and pink, to dark red and dark brown.

Among the Lauraceæ special mention must be made of Belian (*Ensideroxylon Zwageri*). It is one of the strongest known woods, the wood is dark brown in colour, very heavy, very hard, very durable, straight grained and splits readily. The local consumption is about 15,000 tons per annum, the exports are negligible.

All the lowland forests could be exploited by modern methods of lumbering.

Such areas exist in the west between Lundu River and Cape Datu, in the Lingga River, in the Rejang Delta behind the mangrove forests, at Kedurong, near Bintulu. Of the above areas all are accessible by water, but not all to big ships.

Unfortunately, it is quite impossible to give any exact figures as to the available area, but it certainly exceeds 3,000 square miles. Such forests will yield 2,000 cubic feet of timber per acre.

LIST SHOWING THE MORE IMPORTANT TIMBERS OF SARAWAK.

Native Name.	Scientific Name.
Dipterocarpaceae.	
Chengal	*Balanocarpus sp.*
Giam	*Hopea sp.*
Kapur	*Dryobalanops sp.*
Keruing	*Dipterocarpus sp.*
Meraka	*Dipterocarpus sp.*
Meranti	*Shorea sp.*
Merawan	*Hopea sp.*
Engkabang Pinang	*Isoptera sp.*
Penyiau	*Shorea grandi flora.*
Mangbesi	*Hopea sp.*
Resak	*Isoptera sp.*
Seraya	*Shorea sp.*
Tekam	*Shorea sp.*
Urat Mata	*Parashorea.*
Leguminosae.	
Merbau	*Intsia sp.*
Keranji	*Dialium sp.*
Sepetir	*Sindora sp.*
Tapang	*Koompassia parvi flora.*
Mangeris	*Koompassia malacceasis.*
Lauraceae.	
Belian	*Ensiderexulon Zwageri.*
Kepla	*Cinnamomum sp.*
Medang	*Many species chiefly Cinnamomum.*
Meliaceae.	
Nyireh	*Xylocarpus sp.*
Combretaceae.	
Teruntum	*Lumnitzera littorea.*
Moraecae.	
Tampinis	*Sloetia siderozylon*
Guttiferae.	
Penaga	*Mesua ferrea.*
Bintangor	*Calophyllum sp.*
Anacardiaceae.	
Rengas	*Melanorrhoea sp.*
Rosaceae.	
Selunsur	*Parinarium sp.*

CASUARINACEAE.

Ru .. .. .. *Casuarina equisetifolia*

OLACACEAE.

Petikal .. .. *Ochanostachys amentacea*

Embawang .. .. *Scorodocarpus borneensis*

LOGANIACEAE.

Perepat .. .. *Fagraea sp.*

IMPORT TRADE.

The export trade of Sarawak has been considered in detail; this is not necessary in the case of the imports.

The increase in imports is not due to a rapid increase in population, but to the importation of machinery for the development of industries in the hands of European firms. Sarawak is not a manufacturing country, so there are no imports of raw materials.

In 1920 the import of iron ware, machinery chemicals and motors amounted to $3,500,000, steam and motor launches to $450,000, treasure to $1,625,000, sundry stores for manufacturing plants to probably $300,000, making a total of nearly $6,000,000 or nearly 50 per cent. of total imports.

THE GOVERNMENT OF SARAWAK.

We have reviewed the course of prosperity of Sarawak from its earliest days to the present time, and have seen a practically uninterrupted advance; it is not perhaps out of place to consider the cost of this advance. Has it been effected with economy or has the cost to the Government been out of proportion to the benefits received ?

SARAWAK:
ITS REVENUE AND EXPENDITURE FROM 1870 TO 1920.

	Revenue.	Expenditure.
	$	$
1870	122,842.—	126,161.—
1880	229,718.—	203,583.—
1890	413,113.—	362,779.—
1900	915,966.—	901,172.—
1910	1,417,360.—	1,263,063.—
1920	2,646,265.—	2,352,300.—
1921	2,840,171.—	2,331,605.—

These figures will show that the cost of development has been by no means excessive.

It should be noted here that the development of Sarawak, has taken place without recourse to loans either internal or external. Whether this policy has been the best it is not for me to say; but the fact remains that at the present time Sarawak has no National Debt and no Income Tax! Accommodation in Sarawak is limited, so I trust that the publication of this fact will not cause a rush of long-suffering taxpayers from England to this Arcadia!

In 1920, the cash assets of Sarawak were $2,500,000, and its cash liabilities under $150,000. In addition to these assets, the Government has investments in England.

It has been, and is still constantly said, that the Rajahs of Sarawak have been adverse to the opening up of the country by European capital. Such a statement is absolutely untrue, and has doubtless originated from those who, in the past, have been disappointed in their hopes to exploit the country to the detriment of the inhabitants, and the Government, and, in fact, everyone but themselves and their shareholders.

It is the policy of the Rajah of Sarawak, as it has been with his predecessors, to maintain the rights of natives within his kingdom; to such a policy, applied to Sarawak, there can be no objection. It must be remembered, however, that there are only 600,000 inhabitants of Sarawak, with an area of 50,000 square miles, and it can be easily realised that in a country so vast, with so small a population, the development of the kingdom can be undertaken without interference with native rights.

While it is true that under the present system, or rather lack of proper system, the Kayans and Dyaks, who form the greater proportion of the inhabitants of Sarawak, use their hill padi lands once only in seven years, even so this amounts to a reserve of padi lands for about 3,500,000 persons only.

Java, with an area of 37,000 square miles, can support over 40,000,000 persons and still leave room for the planting of tea, chincona, sugar, tobacco, rubber and the working of jungle produce. Surely there is room for development in Sarawak without interference with native rights.

Having disposed of the myth that Sarawak may not be developed with English capital, let us summarize what the Government of Sarawak has or has not done to push forward its development.

Concessions have been granted for minerals and oil; encouragement has been given to agriculture, and also to the development of jungle produce. We have seen that in some cases this has resulted in success, whereas in other cases it has failed.

In one respect Sarawak is particularly backward, and that is in respect of roads and general means of communication. Too much reliance has been placed on the adequacy of the many rivers as means of communication. Trunk roads are necessary throughout the State, with branch roads to open up the untouched jungle between the rivers leading into the main trunk roads, and where necessary, leading to shipping ports on the various rivers. It should be remembered that most of the land on the banks of the rivers of Sarawak is used by natives for padi, etc., and it is, consequently, difficult for those wishing to open up land to find available sufficient space without interfering with native reserves. Roads as suggested above would open up entirely new land, and would not interfere with native reserves, except, perhaps, in the western districts of Sarawak Proper.

An experiment has been made in railway building which has not been continued. Perhaps the existing line is useful for local traffic, but I consider its continuation through the country should await the development of roads.

I have endeavoured to sketch the possibilities of Sarawak as a new field for agricultural development; in addition, I have discussed the exploitation of the minerals and oil resources; the policy of the Government has been briefly referred to, and it is to be hoped that this paper may draw the attention of the British public to the State. I feel these notes would not be complete without a warning that sufficient labour to develop any industry on a large scale cannot be obtained locally. With China and Java within easy distance, however, an unlimited amount of labour is obtainable at a reasonable cost.

In conclusion, I would make brief reference to the present Rajah, His Highness Charles Vyner Brooke.

He succeeded his father in 1917, at a time when the future was clouded by affairs in Europe. He has a very intimate knowledge of his people and his country. He has already seen his country safely through the crisis of threatened starvation, owing to the failure of rice crops in 1919-1920, and it is now emerging from a period of depression in trade to an extent hitherto unknown.

It cannot be doubted by those who know him personally, that he will continue to rule Sarawak under the same carefully considered policy by which his predecessors have so amply proved their capacity to uphold their unique position in the world—building up trade on solid foundations, and, while respecting native rights, encouraging the development of resources and fostering the industries of the country.

DISCUSSION.

THE CHAIRMAN thought Mr. Collingwood Hughes should be acquitted of the charge of being a gramophone record. He did not know that the subject offered very much scope for general discussion, and in any case, the author was beyond the radius of attack. In spite of the fact that Mr. Hughes had expounded the paper with such admirable lucidity, he could hardly be held responsible for the statements made in the paper. There were, however, present that day several old Sarawak officers who perhaps might take part in the discussion.

SIR PERCY CUNYNGHAME, Bt. O.B.E., thanked both the writer and the reader for the very interesting account of Sarawak that had been given. A country which, after nearly a hundred years of European administration, had no national debt and no income tax, was certainly one deserving of attention, perhaps even of the Chancellor of the Exchequer. He himself was for a great many years in Sarawak and, therefore, had always taken a deep interest in the country and continued to do so. In listening to the paper, one realised the developments, the principal one probably being the magnificent oil field in the Baram district. In his time the existence of oil was known, but the field itself had not been proved or developed. There were two gold mines which had been since closed down. They were very profitable to the company working them, and the Government drew royalties. The mines were now closed down because the ore was supposed to be worked out. He would, however, be a very bold man who ventured to prophesy that no further discoveries of gold or other minerals would be made in Sarawak. There were traces of gold all over the country. From the geological point of view, it was, practically speaking, unexplored; geological exploration was a most difficult matter because the over-growth was so great. In other countries there were indications on the surface of what was underneath, but in Sarawak the whole place was grown over by jungle. He believed that some

day further discoveries of precious minerals would be made in Sarawak. It was known that diamonds existed, and he thought the biggest stone found in Sarawak was 72 carats, and known as the Star of Sarawak. Diamonds had been only worked by natives hitherto, but possibly, if the work was undertaken by Europeans, who knew the proper method of searching, good results might follow. Apart from those somewhat doubtful possibilities, there were two things which were beyond doubt, with which he thought the future of the country was bound up. One was the development of the coalfields and the other timber. The coalfields hitherto had hardly been scratched. Timber existed in great quantity, and had been exported to China for a long time. Sago, pepper and rubber would be always exported in varying quantities according to price ruling at the time. With regard to the necessity of making roads, he quite agreed that if roads were made through the country it would enable people to get at the land which lay between the rivers. At the present time, all communications were by water; it was almost impossible to understand what magnificent waterways the country had. Every town and village and every settlement was on a river, and every important station had its steam launch. It was obvious, therefore, that all the development had taken place on the banks of the rivers. If the country was to develop more labour would have to be imported, and the best labour was Chinese. There were plenty of Chinese in the country at the present time, and they were a most desirable population. They were the mercantile community and the principal agriculturalists and also miners. A Chinese merchant of good standing was as honest as a European, and his word was his bond. Many of them had made money, and were very liberal and generous, and were in every way fitted to take a part in the Government of the country. The Malay would not settle down to any work and stay in a place year in and year out, as was necessary where there were factories and mines. The interior of Sarawak was very little known, but it was a country of forest-clad hills, fertile valleys and beautiful streams, and a climate which in comparison with the coast, was cool and invigorating, and he thought it was in that part of the country that the future lay. It was not accessible at the present time, but he hoped it would be made so, and then Sarawak would be one of the most attractive countries in the Far East.

Dr. Charles Hose said the paper was an excellent one and he could endorse all Sir Percy Cunynghame had said. He congratulated the Society on having had such a useful and important paper. He used to be a Member of the Royal Society of Arts many years ago, and it was his intention later on to become a Member again. He had read a paper himself a short time ago, at the Royal Colonial Institute, on the system of government in Sarawak. Although he tried to deal with trade to some extent, Mr. Parnell's paper described the resources of the country and the trade in a way which he should very much like to have done, because such a paper had been wanted for some time. There was one point he did not quite agree with. Mr. Parnell had quoted Crawfurd as stating that there was a great deal of tin in Sarawak, but he himself had never been able to find any trace that might be of commercial interest. It was said that there were lodes of tin in Upper Sarawak, but he had never come across it, nor heard of anyone who had.

Mr. Alexander Reid, M.Inst.C.E., F.G.S., said he had been very much interested in Sarawak, not as a Government official, but as one who had visited it on several occasions, and he wished to thank the author for his interesting paper, and to express his gratitude to the Government officials of Sarawak for the great courtesy which they had always shown him. He was engineer to the Island Trading Company, who were treated in the most courteous manner by the officials. In passing along the rivers of Sarawak, he had been always obsessed with the idea that some people should put down 10 or 20 millions sterling, and open up Sarawak with excellent roads. He was greatly interested in geology and mining, and was sorry to say he could not agree with Dr. Hose on the possibility that tin and other minerals would not be found in Sarawak in quantities when the country was properly explored.

The Secretary (Mr. G. K. Menzies) said there was one point in connection with the paper on which he should very much like to have some further information. He had been told recently by one of our greatest experts in oil, that the Sarawak oil field was second only to one oil field in the British Empire in its potentialities. If it was of that tremendous importance, the sooner it was known the better. He did not think there were many people in this country who had any idea of the enormous importance of that field, and he should be very glad if somebody could confirm what he had been told.

Mr. Willes Johnson said with regard to the potentialities of oil, he thought the fact was, according to the information he had had from the company working the field, that at the present time it yielded the second largest output of any oil field in the British Empire, the largest being in Burma. The exports had increased enormously in recent years, and last year amounted to 400,000 tons, and he believed the output so far this year showed a substantial increase over that of last year.

THE CHAIRMAN thought it was a matter of regret that Mr. Parnell could not be present to appreciate the manner in which his paper had been presented and discussed. It was not every man who had the gift of speaking, as distinct from the gift of speech, who would come forward and read another man's paper, and he thought that act was especially remarkable in the case of a very busy man, a Member of Parliament, who had plenty of interesting topics of his own. The meeting should mark its appreciation of what Mr. Collingwood Hughes had done, by according him a very hearty vote of thanks.

The motion was carried unanimously.

MR. COLLINGWOOD HUGHES said it had given him very great pleasure to be present and perform such a slight service for the Royal Society of Arts. It was true he was a busy man, but he also had a very inquisitive mind, and always liked, if possible, to acquire information and get into the closest possible touch with matters which he had not been previously interested in. After reading the paper, he rather felt inclined to give up his Parliamentary career and go to Sarawak, where there was no Income Tax and no National Debt. He believed that in such circumstances one could be a most successful politician, which was a very difficult matter in a country like Great Britain, burdened as its people were with taxes, with little income, and with such a great number of politicians.

A vote of thanks to the author concluded the meeting.

Mr. D. R. Broadbent, A.M.I.E.E., A.M.I.M.E., writes:—

"With reference to the most interesting paper on "Sarawak: its Resources and Trade," I think our silversmiths, etc., would do well to buy more antimony from Sarawak than they do now, and amalgamate it with their wares, for example, in the handles of pocket knives, backs of hand mirrors and other articles. Continental manufacturers have done so for many years past.

The climatic conditions of these Isles, especially in London, is not at all suitable for pure silver goods, as they tarnish—as is well known—too much and too rapidly. These goods, of course, would be sold as a silver amalgam.

TREATMENT OF SILVER ORE IN DUTCH EAST INDIA.

Enhanced values of the metal have considerably increased the importance of the silver mining industry in Dutch East India.

The ore at Tambang Sawah, which is the black oxidised variety mixed with dioxide of manganese, similar to the ores found in Mexico and the United States, is rich in silver with faint traces of gold.

Reduction of the ore was formerly very troublesome, owing to the insolubility of the oxides, but these are now driven off by roasting in a reducing gas fire. The ore is broken into pieces of about one inch cube and placed in rotary furnaces of the Clevenger type, the lower ends of which are provided with stationary receivers having air-tight joints. From these it is discharged into troughs containing a solution of cyanide of sodium, contact with air being effectually avoided, and is finally removed by an endless conveyor. The furnaces are 3ft. in diameter, 75ft. long, and lined to a thickness of 10in. with fireclay. They are capable of roasting 50 tons of ore per diem. The gas and air essential to combustion enter the upper part of the stationary receiver, but the ordinary method of burning gas in air is reversed, as the whole of the furnace is filled with producer gas and only the requisite amount of air is admitted. With this arrangement, the same amount of heat is produced, but the flame is strongly reducing and capable of consuming the oxygen which the ore liberates. The process of reduction is most active at the lower end of the furnace, and only final traces of hydrogen and carbon monoxide are consumed at the upper end by the escaping hot gas.

Cyanide of sodium lye will dissolve from 90 to 96 per cent. of the silver and practically the whole of the gold contained in the roasted ore, as compared with only 20 to 30 per cent. of the silver in the non-roasted ore. The furnace consumes a minimum of producer gas, as the exact proportions of air and gas needed for perfect combustion can easily be adjusted during working. The temperature required varies between 550° and 650° C.

Gas is generated from wood in Akerlund gas producers of the down-draught suction type, and is deprived of tar, heavy hydro-carbons, etc. The bulk of the remainder of the impurities is changed into carbon monoxide and hydrogen by passing through a red hot bed of charcoal. No gas holder is required, as the supply is regulated by the gas exhauster. The quantity of fuel used for reduction is approximately 14 cubic feet per ton of ore.

The roasted ore is ground in a ball mill and mixed with cyanide of sodium before passing through a tube mill, in which it is reduced to a fineness that leaves only 6 to 10 per cent. on a wire screen with 200 meshes per square inch. The greater part of the silver is dissolved in the mill, although further extractions take place in Dorrs agitators and concentrators. The effluent is finally passed through a rotating Oliver vacuum filter, where the last traces of metal are retained. Recovery of the latter

takes place by the T. Crowes process, in which the solution is deprived of air and the silver and gold precipitated in a filter press by the aid of a very small amount of zinc. The effluent cyanide of sodium is repeatedly brought up to normal strength and used again for fresh extractions. The finely divided gold and silver is then dried, treated with sulphuric acid to remove the zinc, and melted into bullion, the zinc being recovered by roasting with saltpetre.

THE DEVASTATED AREA IN FRANCE.

M. R. Musset, in an interesting article in the *Annales de Géographie*, describes the extent to which the areas in the war zone in France have been restored to agriculture. Over 8,500,000 acres, of which nearly 5,000,000 were arable, were devastated by the war. These lands are classified, according to the degree of damage, into blue, yellow, and red zones. In the blue zone the war effects were chiefly limited to the absence of cultivation, leading to the growth of weeds and to the loss of fertility owing to want of manure. The dry autumn of 1920 and spring of 1921 were favourable to the necessary process of cleaning. In these zones great progress has been made with agricultural reconstruction, and the peasants have been able to cultivate at once, no preliminary operations being required. In both the other zones elaborate levelling and clearing operations were necessary before cultivation could be re-started. These were carried out by the State, and are practically complete in both zones. But cultivation is still difficult and costly. In the red zone the necessary measures will take many years, and in certain districts will involve outlay greater than the value of the land, some of which will probably remain permanently waste or be put under timber.

In some areas special difficulties have arisen. In the Verdun district old landmarks of small properties have been obliterated, and it has become necessary to make a re-division of the land. In Picardy and Artois, where the level surfaces facilitated the use of motor-tractors, much progress has been made; but a serious economic difficulty has been caused. Before the war, sugar-beet was the chief crop, combined with stock-rearing and wheat-growing, both of which depended on the staple; for the beet requires a well-manured soil, the cattle were fed on the beet residue from the sugar factories, and wheat as a rotation crop gave high yields. With the complete destruction of the sugar factories beet can no longer be profitably grown; stock-rearing thus becomes difficult and wheat has to become the main crop. Again, in the Ardennes the actual damage to the land was slight, but the small hardy horses which formed the main stock, and which were extensively reared, were carried off, and the characteristic industry thus received a fatal blow. Finally, round Noyon and Lassigny, originally a land of small-holders and of medium-sized properties, the actual reconstruction of the surface has made great progress; but the complete destruction by the Germans of the fruit trees, especially cherries, which played an important part in the local rural economy, is an injury which it will take long to repair.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, JUNE 11.. University of London, King's College, Strand, W.C., 5.30 p.m. Prof. R. Dyboski, "Outlines of Polish History." (Lecture VII.)

Victoria Institute, Central Buildings, Westminster, S.W., 4.30 p.m. Mr. E. W. Maunder, Annual Address, "The two Sources of Knowledge—Revelation and Science."

TUESDAY, JUNE 12.. University of London, University College, Gower Street, W.C., 5 p.m. Prof. G. N. Lewis, "The Structure and Behaviour of the Molecule." (Lecture III.)

At St. Bartholomew's Hospital, Medical College, Smithfield, E.C., 5 p.m. Dr. A. Balfour, "Tropical Hygiene." (Lecture I.)

At King's College, Strand, W.C., 5.30 p.m., Miss H. D. Oakley, "The Conflict within the Greek Moral Idea." (Lecture II.)

Colonial Institute, Hotel Victoria, Northumberland Avenue, W.C., 8.30 p.m. Major-General Sir Frederick Maurice, "The Military Position of the Empire."

Mining Engineers, Institution of, at the Royal Technical College, George Street, Glasgow, 11 a.m. (1) Mr. G. S. Rice, "Coal-dust as an Explosive Agent" (with special reference to the experimental work of the United States Bureau of Mines). (2) Summary of Research Work carried out for the Committee on "The Control of Atmospheric Conditions in Hot and Deep Mines." (3) Mr. H. P. Giffard, "The Recent Search for Oil in Great Britain." (4) Mr. H. M. Cadell, "A Volcano in the Bathgate Coalfield of West Lothian." (5) Mr. D. Ferguson, "The Hurlet Sequence in Renfrewshire and Dumbartonshire and the Evidence of the Basin Structure in the Coalfields of Scotland."

WEDNESDAY, JUNE 13.. University of London, University College, Gower Street, W.C., 3 p.m. Prof. E. G. Gardner, "The Composition of the *Divina Commedia*." (Lecture IV.)

6.15 p.m Sir. Josiah Stamp, "Economical and Statistical Aspects of a Capital Levy." (Lecture IV.)

THURSDAY, JUNE 14.. University of London, University College, Gower Street, W.C., 5.15 p.m. Prof. J. E. G. Montmorency, "Customary French Law." (Lecture VI.)

Chemical Society, Burlington House, Piccadilly, W., 8.30 p.m. Prof. Charles Moureu, "Les Gaz Rares des Sources Thermales, des Grisous et Autres Gaz Naturels."

At St. Bartholomew's Hospital, Medical College, Smithfield, E.C., 5 p.m. Dr. A. Balfour, "Tropical Hygiene." (Lecture II.)

Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.

Central Asian Society, at the Royal United Service Institution, Whitehall, S.W., 5 p.m. Mr. C. L. Woolley, "The Excavations at Ur of the Valley of the Chaldees, 1922-3."

Historical Society, 22, Russell Square, W.C., 5 p.m. The Alexander Prize Essay.

FRIDAY, JUNE 15.. Photographic Society, 35, Russell Square, W.C., 7 p.m. Mr. D. E. Batty, "A Simplified Method of Printing in the Gum-Bichromate Process."

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FRIDAY, JUNE 15, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

ANNUAL GENERAL MEETING.

The Council hereby give notice that the One-hundred-and-Sixty Ninth Annual General Meeting, for the purpose of receiving the Council's Report and the Financial Statement for 1922, and also for the election of Officers and new Fellows, will be held in accordance with the By-laws, on Wednesday, June 27th, at 4 p.m.

(By Order of the Council)
GEORGE KENNETH MENZIES,
Secretary.

SOCIETY'S ALBERT MEDAL.

The Albert Medal of the Society for the current year has been awarded in duplicate by the Council, with the approval of HIS ROYAL HIGHNESS THE PRESIDENT, to MAJOR-GENERAL SIR DAVID BRUCE, K.C.B., D.Sc., LL.D., F.R.C.P., F.R.S., and to COLONEL SIR RONALD ROSS, K.C.B., K.C.M.G., D.Sc., LL.D., M.D., F.R.C.S., F.R.S., in recognition of the eminent services they have rendered to the Economic Development of the World by their achievements in Biological Research and the Study of Tropical Diseases.

PROCEEDINGS OF THE SOCIETY.

EIGHTEENTH ORDINARY MEETING

WEDNESDAY, APRIL 18TH, 1923.

WILLIAM PHENÉ NEAL, ESQ., Alderman, City of London, in the Chair.

The paper read was:—

MODERN ABATTOIR PRACTICE AND METHODS OF SLAUGHTERING.

By HAL WILLIAMS, M.I.Mech.E., M.I.E.E., M.I.Struct.E.

In presenting this paper the author is anxious to pass in review several factors which should have the greatest possible influence in deciding under what conditions the animal food of the nation is to be slaughtered and prepared for consumption; to draw attention to the methods employed in the great meat exporting countries overseas; to dwell upon the re-action which fatigue and terror in the live animal induce in the quality of the dead meat, and to show how the exercise of that great quality of mercy, which all humanely minded people would wish to exercise towards the dumb animals that are killed for the purposes of food, can, and does, yield mankind measure for measure in more wholesome, more toothsome, more nourishing meat, and, consequently, in more healthy food.

He wishes further to preface his remarks by saying that from what he knows of butchers and slaughtermen—and in a mild way he has been a slaughterman himself—he will not countenance the general charge which has sometimes been made, that they are, as a class, intentionally cruel. That is not the case. The men have to work to the best of their ability under the conditions and with the implements which are provided for them. The responsibility for cruelty does not lie primarily with them, but it does very definitely lie with those who are responsible for providing the conditions and countenancing the methods under which the men have to work.

PRIVATE SLAUGHTERHOUSES.

In a paper read recently before the Veterinary Section of the Royal Sanitary Institute at Folkestone, Mr. Thomas Parker, F.R.C.V.S., estimated that there are in England and Wales something like 20,000 private slaughterhouses, and he added the remark—with which everyone who knows anything about the subject must cordially agree—that in this country there are very few, if any, premises that could be considered good examples of modern abattoirs. The Report of the Public Health Committee of the London County Council, dated February 15th last, states:—

The methods of slaughter usually adopted in London slaughterhouses are the customary methods, of old standing, and in the ordinary way subject to little change. The first operations in connection with slaughter in licensed slaughterhouses in London are usually as follows. Bullocks are secured to a ring and then struck on the forehead with a pole-axe. The calf is first hoisted by its hind quarters and then stunned. Sheep and lambs are "stuck," *i.e.*, large vessels of the neck are divided, the spinal cord between the neck and head being then immediately severed. Pigs are stunned with a wooden mallet, except that very large pigs are pole-axed, and that it is not usual to stun small pigs before they are killed. During the past 30 years no case of actual cruelty in London slaughterhouses has been brought to the notice of the Council.

It is only too easy to write sensationally on a subject of this kind, and the author has endeavoured throughout to use restrained language befitting the seriousness of the subject.

Of the private slaughterhouses we can say nothing in the way of praise, but a very great deal by way of condemnation. They offend in their lack of every reasonable modern requirement, whether it be connected with Veterinary Inspection, Sanitary conditions, economy in by-products, or humanitarian ideals. In London, private slaughterhouses are steadily decreasing, for while in 1889 there were 692, to-day there are only 153, of which less than 66 are used for regularly slaughtering bullocks; the principal reason for this decrease is not the superior attraction of the Corporation Abattoir at Islington, but the large quantity of imported meat which is sold in the London markets.

Whilst we condemn the private slaughterhouse, we cannot reasonably blame the butchers who own or rent them, or the slaughtermen who use them, because if Local Authorities neglect to provide proper public abattoirs, what alternative have they? It would be just as reasonable to refuse to provide public baths and wash-houses, and then blame people for being dirty. It is because of the absolute impossibility within economic financial limits of ever doing anything to a private slaughterhouse to place it on all fours with a private killing stall in a properly designed public abattoir that it is of no profit to waste time in discussing them further. The private slaughterhouse, except in country towns and villages, should go out of use as soon as possible, but it must be remembered that such a change cannot be made in a hurry. Provide public abattoirs of decent, up-to-date design and construction, and in due course the private slaughterhouses will close themselves, to the great benefit of everyone, and not the least—though he may not at present realise it—to the pocket of the butcher who owns or rents them.

Public slaughter halls exist in a good many towns, but a public slaughter hall and an abattoir are by no means the same thing, and the author speaks with knowledge when he says that there is nothing in Great Britain which can be called an abattoir in the same sense as the institutions overseas are called abattoirs. A slaughter hall is a building which consists more or less of pens or lairs for the living animals, slaughter pens where they are killed, frequently in sight of the dismembered carcases of other animals, sometimes a meat dressing room and cooling room, but of little or nothing else. The butcher hates them because they have all the disadvantages of the private slaughterhouse without the trade privacy which he values so much. There is little or no provision for veterinary inspection, either ante or post-mortem, and no means of economically treating the edible and inedible offal and blood under the best conditions. If the slaughtermen are dirty it is because no means are provided of keeping them clean; the floors and walls are dirty because they are not constructed for easy or, indeed, possible cleaning, and official inspection is often absent because, through the arrangement of the building, and lack of inspectors, it cannot be readily applied.

In the report of the Committee appointed by the Admiralty in 1904, we read:—

The Committee are of opinion that many of the slaughterhouses in this country are unsatisfactory in design, and present features which are objectionable from a humanitarian standpoint.

It appears to be the common practice, even in modern and well-regulated slaughterhouses, to keep the animals which are immediately awaiting slaughter in pens which are mere annexes to the slaughter-chamber itself, and in many cases in full view of all that goes on inside. Moreover, the drainage of the slaughter-chamber is often so arranged that any blood which is not caught and saved, together with other refuse, flows out of the slaughter-chamber into or through the waiting pens, under the noses of the animals awaiting slaughter. The Committee have witnessed this in slaughterhouses of the largest kind.

The Medical Officer of Health of one of our largest cities in reporting upon the Municipal Abattoirs said :—

The position in regard to the slaughtering of animals is practically the same as at the close of last year. The public Abattoir and the associated offensive trades remain in the condition which has been so frequently commented upon. Every effort is made to palliate the nuisances inseparable from the conduct of businesses of this kind in situations which are cramped, confined, insanitary, and entirely unsuitable for the slaughtering, dressing, and selling of animals for human food. . . . . . The lack of refrigerators at the Abattoir has been the cause of meat and offal being condemned and destroyed on account of decomposition.

In these slaughterhouses the bullock to be killed is caught in the adjoining pen—or the animals are tethered in the slaughterhouse itself—a rope or chain is put round his horns or head, the other end of this rope passes through an iron ring in the floor or wall and is sometimes attached to a winch or windlass. For milking cows and hand-reared animals, which have been brought up to trust mankind, the winch is not necessary ; for wilder animals it is, and there is great danger to the men in man-handling a beast, especially Welsh or Scotch animals, under these circumstances. Canadian cattle, now due in large numbers, will not submit to roping and tying, and their struggles result in bruised beef and broken aitch bones. When the winch is worked the animal is drawn along by force to the ring in the floor. The beast naturally strains every muscle to hold back, but the winch on the other side of the wall is too strong and the animal slips along the floor towards the ring, sometimes, if reluctant, urged forward by shoving, tail-twisting, or other cruelties. When its head is drawn so close to the ring that it cannot move it, it is either poleaxed, or a "humane killer" pistol is put on to its head and it is shot. The throat is then cut and the animal bled. In the best establishments the carcase is drawn into another room where it is dressed.

Sheep and pigs are stuck, the latter being sometimes stunned. The edible fats and offals remain the property of the butcher and those he does not want are generally sold to an allied trade, whilst the inedible portions are disposed of in the same way. That, in brief, is a fairly accurate description of the *modus operandi* in pretty well every existing abattoir in the British Islands.

In some cases the animal, whilst being drawn to the slaughter ring, has, by some means or other, escaped. It has then to be re-caught, or in the case of dangerous beasts—and under these conditions beasts can be dangerous—despatched by some other means. In one case within the author's knowledge the animal was ham strung and then poleaxed whilst lying helpless on the ground. In any case, imagine for one minute the state of terror and fever flush of the animal whilst it is being forcibly drawn up to the slaughter ring, with all the sight and scent of carnage in its eyes and nostrils.

Continental Methods.

It is usual to quote the Continental countries of Germany, Scandinavia, Switzerland, and Denmark, as being the last word in abattoir practice. That this idea is largely illusory is shown by a perusal of the appendix to the Report of the Admiralty Committee previously referred to. Generally the abattoirs in these countries are much more elaborate buildings than anything we have. They very rightly pay more attention to cleanliness and veterinary requirements than we do, but beyond the fact that in the majority of cases the animals are stunned before being killed, or are killed with some patent killer, the preliminary work necessary to stun the animal or fix the killer, is often as bad as has just been described in English practice.

As regards the slaughtering, the Report says :—

"Although the mask is not infrequently used, it is the general practice to kill cattle by shooting with an apparatus similar to the Greener. Both methods work satisfactorily, death being, to all appearance, instantaneous, and, in consequence, the pithing cane is not used. As far as could be ascertained, the shooting had no deleterious effect upon the meat, either as regards the bullet or the gas generated by the ignition of the powder, and it was distinctly stated that no element of danger to attendants was apprehended. It is right to notice, however, that the cattle—possibly home-bred—were sufficiently quiet to permit of this type of apparatus being used without difficulty, although it was mentioned that exceptional measures had occasionally to be taken to deal with wilder animals."

The author has witnessed some of the "exceptional measures." They are much the same as ours, but as our animals are not always so tame our measures are more

often "exceptional" than otherwise. At Geneva, the report continues, "there was a marked difference in regard to the treatment of calves and sheep, in that, before they were rendered unconscious, they were hung by one of the hind legs upon a hook on the wall after no little struggling, on a slippery floor, between the animal and the slaughterman. This hanging up process appears to be without advantage except that bleeding may be more rapid."

Probably, the most up-to-date abattoirs are at Cantaranne, Clamecy, Chasseneuil and La-Roche-sur-Yon. The three latter are designed on the two-storey principle, with slaughtering on the first floor and offal treatment on the ground floor. The abattoirs at Copenhagen, Stockholm, and Elsinore, are clean, well built places.

What the Present System Misses.

It will be gathered from the foregoing remarks that in the private slaughterhouse or the public slaughterhall as at present designed, the unfortunate animal has to be got into a position in which it can be pole-axed, stunned with a "humane killer" pistol, or koshered, and that it is in the efforts to get it into this position that the cruelty occurs, blood fevers are generated, and the meat is damaged, both from deterioration within and physical damage without. The very valuable by-products are not realised to the best advantage, and sanitary and veterinary science are not given full scope to exercise their protective proclivities to the advantage of the meat consumer.

These conditions of slaughter were world-wide, and probably would have remained standard practice all over the world, as they are in England to-day, had it not been for the introduction of Mechanical Refrigeration, which made it possible to freeze or chill beef and freeze mutton, and transport it long distances whilst in this state. The first killing in the Oversea Freezing Works, was done by the methods just described. It was held that if an animal had to die, the sooner it did so the better, and stock which had probably been driven many miles, and had arrived at the yards in a hot and exhausted condition, was slaughtered on arrival.

It was found that, for some reason or other, the meat was bad, would not keep. and when it arrived in the English market and was thawed out, it was unsaleable. This condition of affairs, if allowed to continue, would have meant ruin to the Freezing Works, and careful investigations were undertaken to ascertain the cause of so disastrous and mysterious a state of affairs. Ultimately, it was found—at that time by experiment, as the science of blood enzymes had not been developed—that if the stock were allowed to rest at the Freezing Works for some days and were given time to recover from the fatigue and excitements of their journey, the meat was in better condition. From this it was deduced that excitement was deleterious, and the matter was carried forward stage by stage and step by step until the animals, after being fed and rested, were stunned in special pens and killed before they had any idea that anything extraordinary was occurring.

The different steps which were taken before this state of affairs was reached echoed and re-echoed all along the line. It made the stockgrower careful in the handling and driving of his stock, but above all it made the proprietor of the Freezing Works very carefully consider his stock from the time the living animal entered his yards to the time the last component part left the Freezing Works, either as meat, hide, oleo, tallow, meat extract, meat-meal, poultry food, or manure.

The Freezing Works led the way, and when the growing population of the various cities called for public abattoirs, the men who had designed the Freezing Works were ultimately called in to design the abattoirs, and so the perfect abattoir came into being.

The author is privileged to be able to illustrate this paper by some photographs of various parts of different abattoirs, and he wishes to express his appreciation of the permission which has been given him to use the photographs for this purpose. He had hoped to have a cinematograph film illustrating the English and oversea methods of slaughtering and preparing meat, but there were difficulties in the way, particularly with the English methods, which could not be overcome. On some future occasion perhaps it may be possible to do something of the sort, but by that time it is hoped that there will not be the wide difference in system which exists to-day.

It must be remembered that killing and dressing meat is merely a factory process reversed. In the ordinary factory the raw material is brought from many parts of

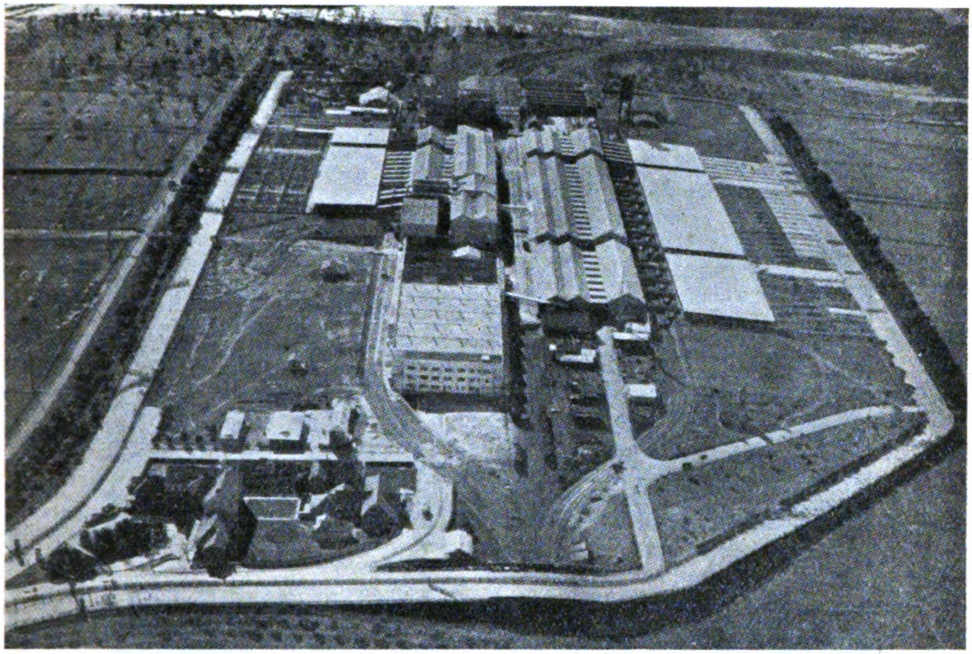


Fig. 1.

the world, fabricated in the factory, and sent out as a finished article. In an abattoir the complete animal is the raw material, but instead of a system of building up there is a system of dismemberment, and the animal is, so to speak, resolved into its component parts. Now each of these component parts, is of value, and it is in getting the last farthing of value out of them that successful abattoir design consists. It is not of the slightest use thinking of abattoirs in terms of bricks and mortar as one might of an ordinary building. The secret lies in the details, and only those who have had packing house experience can tell what these details ought to be, and in what part of the process they should be placed.

Fig. 1 is a bird's eye view of one of the largest and finest abattoirs in the world, that o' Holmbush Bay, Sydney, N.S.W. It is the property of the Metropolitan Meat Industry Board, and is the public abattoir for the City of Sydney, and the centre of a very large meat export industry. The inception and construction of this abattoir were looked upon in the meat world as an object lesson of what not to do. The circumstances connected with it were, happily, somewhat unique, because as a rule people who have money, especially public money, to spend, take care to place the work in qualified hands. We have had over here recently one well-known example of the folly of neglecting this rule, and it is to be hoped that the lessons will sink home in both hemispheres. The *Pastoral Review* in 1919, tells the story:—

"The trouble in the early days of the conception of the new scheme was that, although there was a general recognition of the necessity for an improvement upon the antiquated Glebe Island methods and buildings, there was apparently no one connected with the scheme who was possessed of the requisite technical knowledge of such work. The result was that architects, draughtsmen, and engineers, all in their own individual, and, to an extent, independent way, designed buildings and plant which may or may not have been triumphs of designing skill, but were not of much value for the actual work of the future undertaking. During the many years that the undertaking was in course of construction there was never connected with it a controlling expert versed in the numerous requirements of a modern Abattoir. The early plans were defective by reason of the designing being in the hands of those who knew very little about the construction of such an establishment. When at last outside criticism of the grave mistakes that were being made was indulged in, the Government of the day awoke to the fact that there was something radically wrong in the execution of the whole scheme, and made an attempt to put things right. Unfortunately, however, the men who were appointed to do so were as inexperienced in the special designing that was

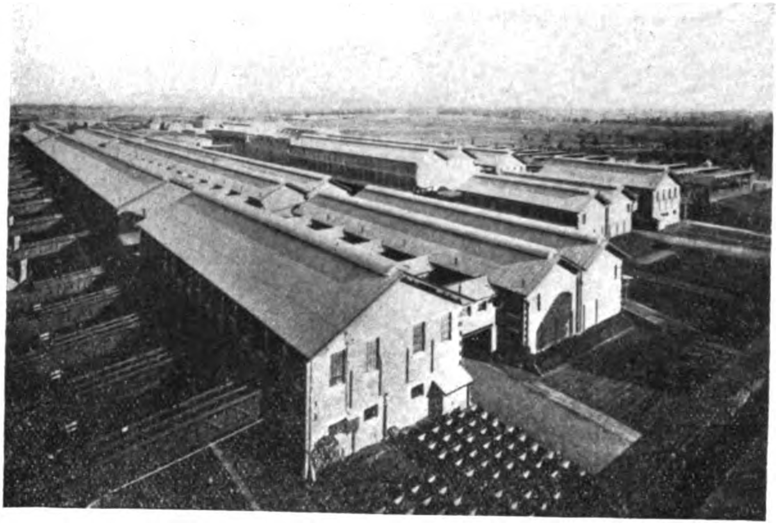


Fig. 2.

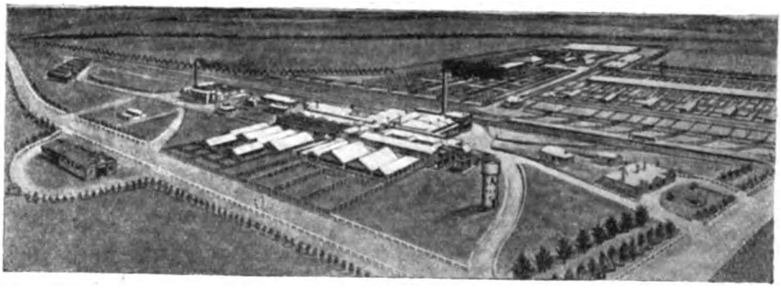


Fig. 3.

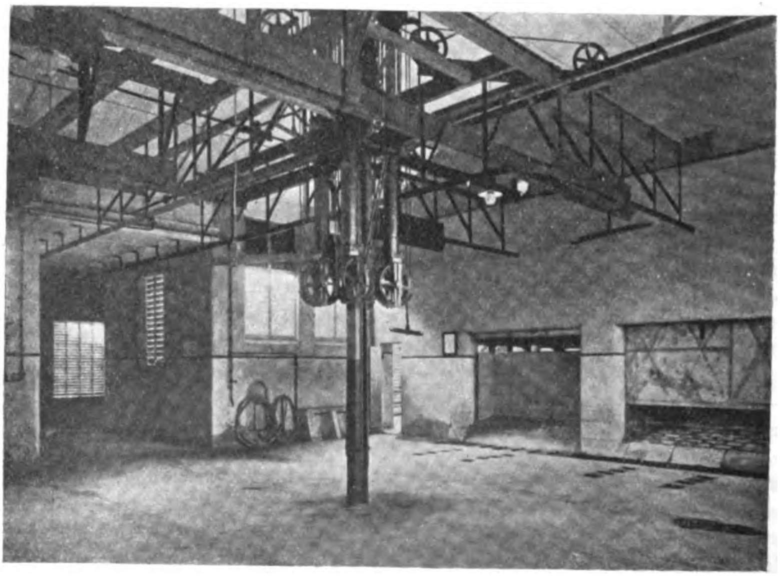


Fig. 4.

necessary as their predecessors, and the resuls was further errors involving the expenditure of hundreds of thousands of pounds without improving the position. There followed a series of building, pulling down, redesigning and rebuilding, and still without approaching very closely to the objective of a really up-to-date Abattoir. There were certainly some sections of the scheme worked out with considerable skill, and many of the buildings are, from an architect's and builder's standpoint, deserving of special mention, but since they have not very well fitted in with the general principles of a broad scheme of abattoir construction, their value is considerably minimised. When at last the Government became fully conscious of the problems involved in the work of designing an establishment of this magnitude, further efforts were made to remedy the defects that had been made in the early and subsequent stages of construction. To an extent these efforts produced good results, but it became evident to the Government that the appointment of someone possessed of special qualifications to supervise the undertaking even at this late date, was an imperative necessity.''

Ultimately the abattoir was taken over by the present Board, who largely re-built it; wrote off £700,000 as wasted capital; and, to quote the *Imperial Food Journal* —''within the space of a few years has changed what was a 'white elephant' of a growingly objectionable character, into a state asset that has exacted the admiration of the world's meat experts.''

It will be noticed that the abattoir is double; cattle and calves on the right, and sheep, lambs, and pigs on the left. The open stock pens are on the two outer sides. Next come the covered pens to rest the animals and protect them from the weather; then the bridges leading to the individual slaughter pens, each with its meat dressing floor, hanging rooms and chill rooms. From the latter the meat is despatched to the city for consumption. The abattoir is intersected by three double railway tracks and two roads, whilst two other roads form its boundaries. Stock is delivered by rail or road.

A feature of the abattoir—Fig. 2—which, with the same object, is unknown in this country, is that it consists of two floors; the killing and dressing is done on the upper floor, whilst the whole of the offal is delivered through chutes to the floor below and is treated there, the inedible portions going direct to the digester house where they are dealt with in a sanitary manner and turned into saleable products. The revenue of the Board is derived from various sources—(1) the collection of fees or dues for services rendered, the sale of by-products, sale of animal and poultry foods, and (2) the rentals derived from special buildings which have been erected for operators such as meat canners. In 1921 the Board was able to report that after paying to the Government the sum of £45,000 as interest on capital cost, there remained a balance of approximately £60,000 as excess of revenue over expenditure.

Fig. 3 is a bird's eye view of the Municipal Abattoirs and Stock Markets at Adelaide. These were called into being under the Metropolitan Abattoir Act of 1908, and were initiated and carried to a successful conclusion by the City Council of Adelaide, the main object being to secure a pure meat supply. Its various Acts of Parliament give the Board an absolute monopoly of the slaughtering of stock within its area. Under these conditions the scheme has to be a very comprehensive one, and includes the slaughtering of cattle, sheep, lambs, pigs and calves, cold storage and chilling chambers, the manufacturing of by-products, such as beef-dripping, mutton-dripping, mutton and beef tallow, lard, mixed tallow, blood manure, bone dust, bone manure and chicken food. The Board also delivers the carcase meat direct to the butcher's shops at a flat rate wherever they may be situated within the Board's area. The animals are, of course, killed in the most modern and hygienic premises, and under the most scientific conditions. Ante and postmortem examinations are carried out by a trained staff of inspectors, at the head of which is a qualified Veterinary Surgeon. It is interesting to note that the fact that the Board themselves undertake the slaughtering of stock and delivery of the carcase meat to the butchers' shops was at the direct request of the Master Butchers of the area, who, at their own desire, ceased to be butchers and became meat purveyors. Over 150 tons of meat are delivered to the shops on a busy day, and the annual revenue is over £200,000.

Fig. 4 is a view in the slaughterhouse and shows the stunning pens, one with the door raised, the other with the door in the position in which it is when the animal to be killed enters the pen, is stunned, and rolls out on to the floor of the slaughterhouse.

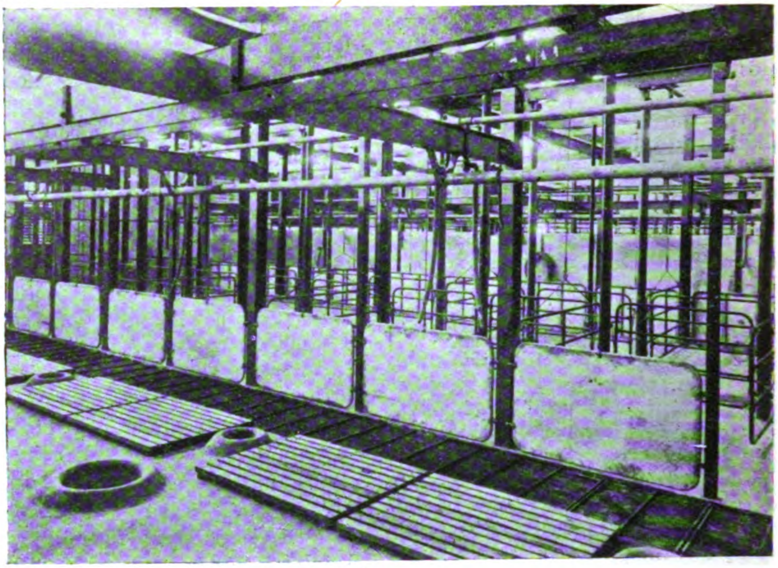


Fig. 5.

Fig. 5 illustrates the sheep slaughter bank, and shows the openings of two offal chutes leading to the floor below.

Fig. 6 shows the other end of the chutes in the Offal Department where the offal is prepared.

Fig. 7 illustrates the manure department or tank room, where the inedible offal, blood, etc., are treated, and Fig. 8 where it is dried under vacuum.

Fig. 9 which may be introduced here, is a diagrammatic drawing of a digester department of a somewhat similar character, designed by the author.

Fig. 10 is a view of the lower floor of another digester department designed by the author. The material spread out on the floor, and in bags, is dried blood. This and the other products of this department are all of very considerable marketable value and secure a ready sale.

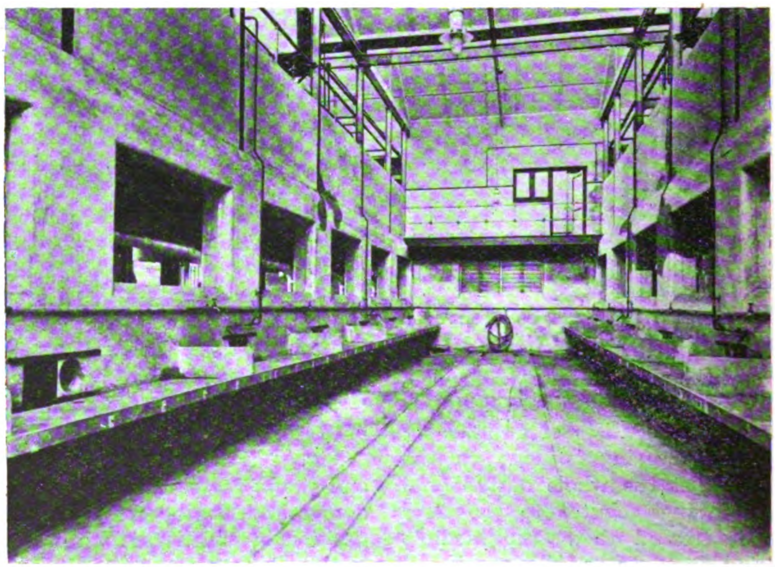


Fig. 6.

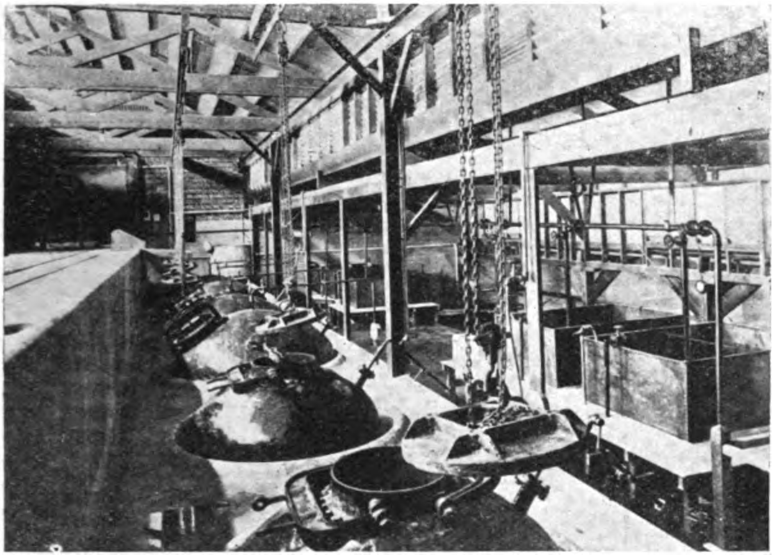


Fig. 7.

Some further particulars of the Adelaide Abattoir, and a brief account of the work done by the Board, are printed in the appendix. Figs. 11 and 12, are borrowed from Mr. Davis' excellent book "The Modern Packing House" and illustrate the method of stunning cattle with a 4lb. hammer. This is the system used in North and South America, as well as in Australia and New Zealand. Fig. 11 shows the striker in the act of striking, whilst Fig. 12 shows the stunned beast which has rolled out on the floor, about to be hoisted for sticking, heading, etc. The next two figures show the automatic stunning pen invented by Mr. W. H. Medcalf, to whom the author is indebted for the photographs. It is portable and can be used in any slaughterhouse, whether private or public. Fig. 13 shows the animal in the pen with his head held high, trying, though ineffectually to see out of curiosity, what

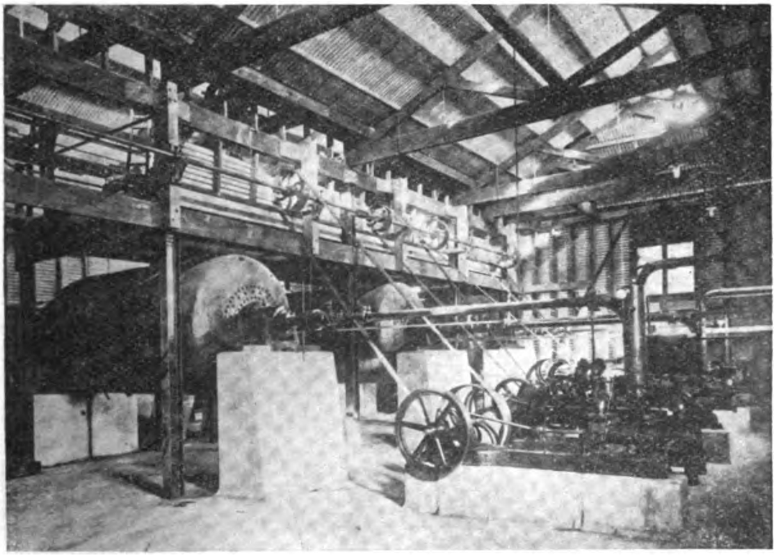
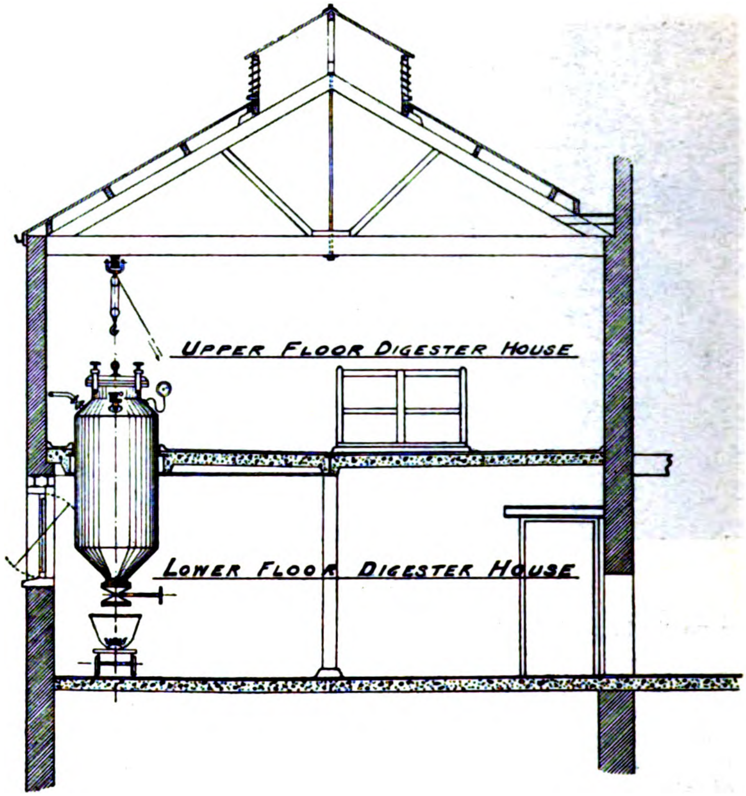


Fig. 8.



CROSS SECTION.

Fig. 9.

Fig. 10.

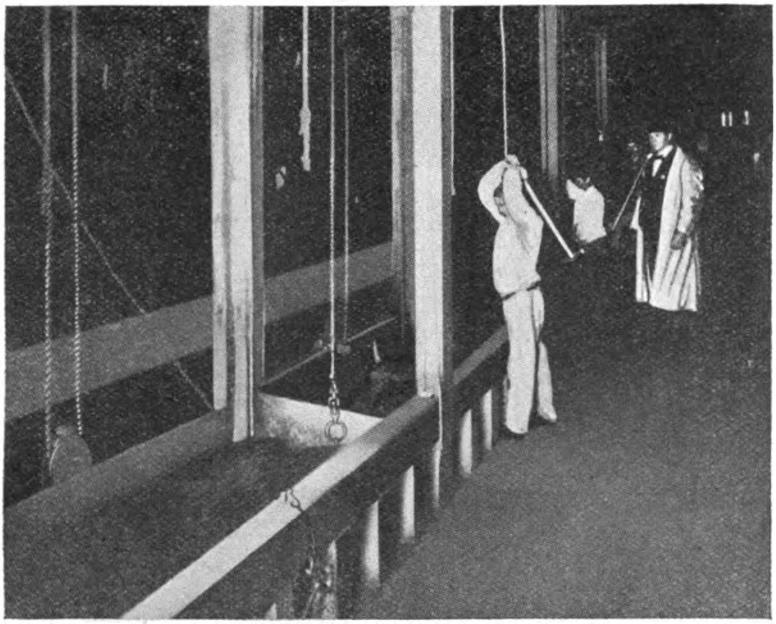


Fig. 11.

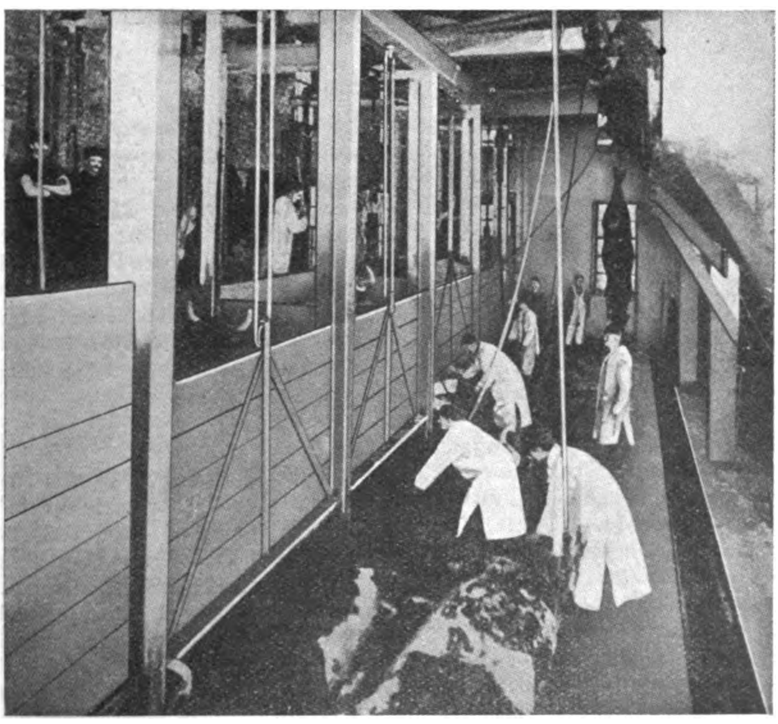


Fig. 12.

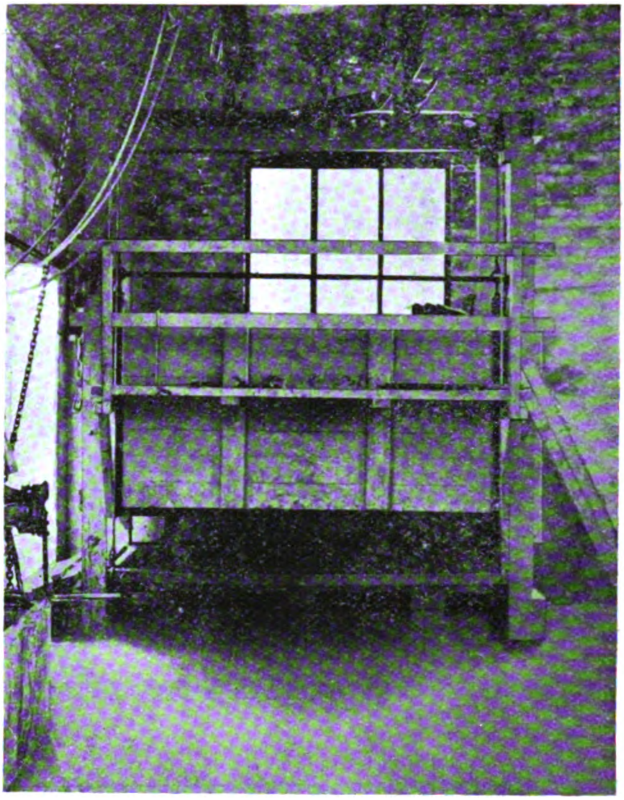


Fig. 13.

is going on. The striker stands on the platform immediately behind the animal's head, and Fig. 14 shows the stunned animal automatically tipped out of the pen and lying on the floor after it has been struck.

The next slides to be thrown on the screen are views taken of the Drogheda Works of the Irish Packing Company, which were designed by Mr. Medcalf, to whom the author is indebted for the slides and photographs from which the blocks were made. Some of these are not reproduced in the text. Fig. 15 shows the slaughter floor with the stunning pens arranged somewhat like those at Adelaide, and, as shown in Figs. 13 and 14. Fig. 16 shows the carcases hung up for bleeding.

The following illustrations are views from a Bacon Factory designed by the author, and capable of dealing with 3,000 hogs a week. This is not a large establishment, but it serves to illustrate principles.

Fig. 17 is a general view of the factory. Fig. 18 shows the pig pens with their double hung gates arranged so that they can be hinged at which ever side is desired. Fig. 19 shows the gentle slope up which the pigs travel at their own pace to the slaughter floor. Figs. 20 and 21 are views of the slaughter floor. Fig. 22 is the large hanging room with its overhead track and louvred sides. Fig. 23 is the sausage room. It will be noted that all walls in the meat rooms are finished in white tiles, that all corners are rounded, and that the building is kept scrupulously clean.

The Ideal Abattoir.

In an old country like this custom dies hard, and the most enthusiastic reformer would recognise at once that it will be many years before a system of municipal meat killing and distribution, as at Adelaide, could be introduced into England. There is no doubt, however, that there is a very wide gulf between the private slaughter-house and the public slaughter halls, which we possess at present, and these Dominion Institutions, and that whilst the time is not ripe for the full organisation

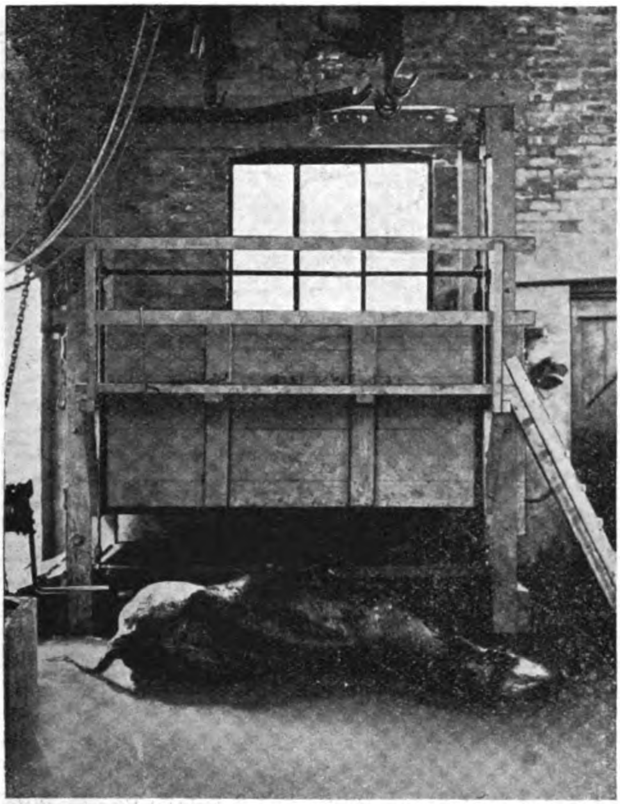


Fig. 14.

of the latter, there is a very strong feeling amongst responsible opinion that we ought to have something very much better than our present premises. There is also little doubt that if the general public had the ghost of an idea of the conditions under which the bulk of our home killed meat is driven, laired, slaughtered and dressed, they would turn with one accord to the cleanly produced and inspected imported meat, the trade in which would receive the greatest fillip it has ever had. The present system is not fair to the butcher who is trying his best under difficult circumstances; it is most distinctly unfair to the farmer who grows beautiful meat only to run the risk of having it spoiled; and it is, most of all, unfair to the people who have to eat it.

It is, the author thinks, beyond dispute that it is essential for the proper protection of the people's meat supply that abattoirs should be established and managed by Public Authorities, and that if properly managed they would pay their way. It will be interesting to try and form a mental picture of a modern English municipally-owned abattoir consisting of a cattle market, with its resting pens, slaughterhouse with its adjuncts, and a dead meat market, and describe briefly what we see. The cattle and sheep markets will be generally as illustrated in Figs. 24 and 25, though they will be constructed of iron and reinforced concrete instead of wood. The resting pens, where the animals are taken after sale, will be covered in and provided with water troughs and fodder racks. In these pens the ante-mortem examination will be carried out and a suspect pen will be provided where any animal which is under suspicion can be put for further observation. Adjoining the suspect pen, and near the digester or tank house, will be the slaughter yard for diseased animals. This is quite different and well away from the other slaughtering pens. Any animals which on this ante-mortem examination are suspect are so marked that their identity is retained until after the post-mortem examination.

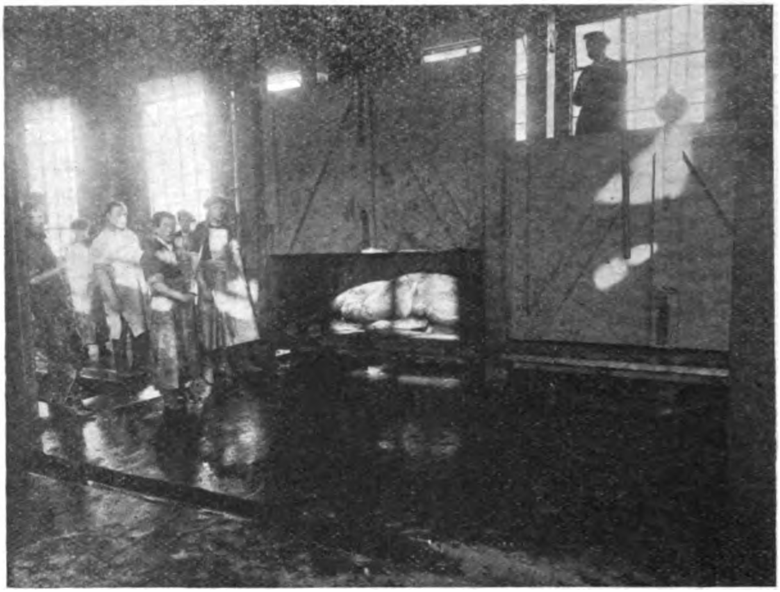


Fig. 15.

The abattoir will consist of a number of separate, but identical units. Each unit will be quite private to the butcher who rents it and will contain its lairage and resting yards, its slaughter and hanging rooms, with its offal department underneath, its chill rooms and its stall in the Central Meat Market. It will also be provided with access to roads for removing its offals and its dressed meat, so that meat can be taken either to the meat market or to any other destination. There will be units for cattle and sheep, some double killing and some single killing, and separate slaughterhouses for pigs. We will examine one of these cattle units. From the resting pens, the

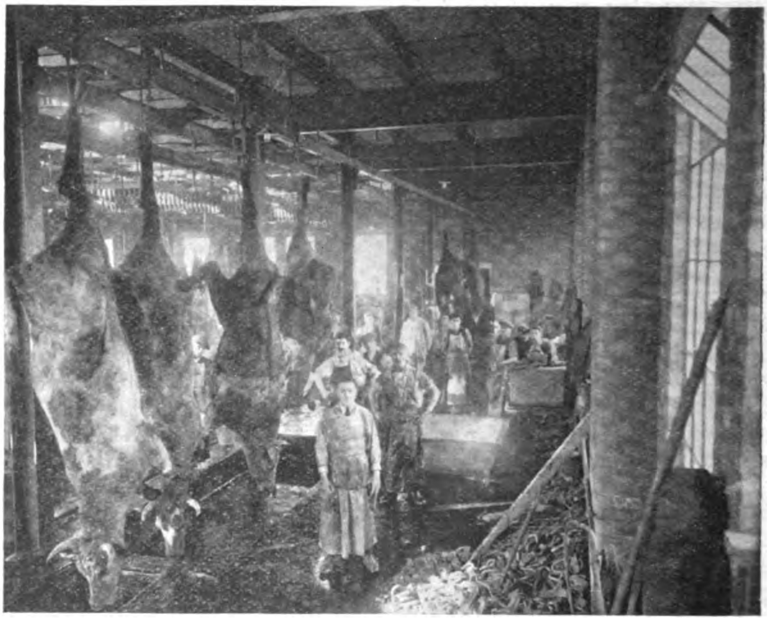


Fig. 16.

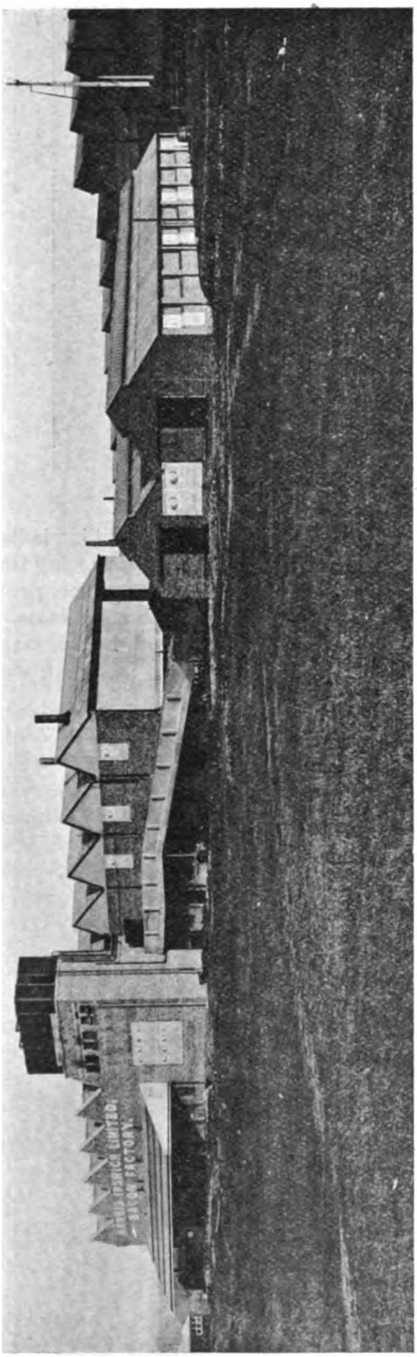


Fig. 17.

animals will be driven up an inclined way with an easy gradient, as previously shown in Figs. 2 and 19. Any reluctance to travel up this path, which is only wide enough to take one animal at a time, will be overcome, not by blows or tail-twisting, but by the animal being quietly urged forward by receiving a mild electric shock from an electric tickler, which is a stick having a flat iron end in electrical contact with one pole of a low voltage circuit. The beasts will be admitted one at a time into the stunning pen, which will be as illustrated in Fig. 4, or in Figs. 13 and 14. In this pen the animal will stand, and, as all cattle are curious, it will raise its head to see what is going on around it. Whilst in this position it will be struck on the head from behind by a 4lb. hammer, and it will at once collapse on the floor stunned. As it falls, the floor automatically tips and rolls the animal out on to the floor of the slaughter room. The butchers now take control, and the animal is at once shackled round *both* the hind legs and raised by the electric winch shown in Fig. 26, and put on the bleeding rail either by hand or by an automatic lander. This operation is a matter of a few seconds, and in this position, whilst still insensible, but of course still alive, the throat of the animal is cut, and, whilst the heart is still beating, the blood gushes out into the grating below, from which it is at once pumped into the cooking vats, pressed and dried for fertilized or meat meal as in Fig. 9. If albumen is required for industrial or food purposes the blood from each animal is caught in separate pans, and after analysis is specially treated, the residue being dried for fertilizer.

The animal will hang on the bleeding rail, which will be made long enough for the purpose, for at least 10 minutes, and longer if possible, up to 20 and 25 minutes, before any other operation is attempted. This will allow a thorough bleeding and will yield a whiter carcase; it is, of course, the blood that has to be got rid of. The operation of heading follows. The carcase is then lowered from the rail and "pitched up" in position on its back on its dressing bed ready for the subsequent operations, which it is unnecessary to detail here. After these are finished and the brisket and pelvis bones have been sawn through, the carcase will be raised to the hanging rail by another winch, where the rest of the operations, including veterinary inspection, will be completed.

At this stage, the entire carcase is washed down with hot water and dried with hot cloths. Clean cloths are placed under the kidneys and elsewhere to catch any blood drops which may come from the larger

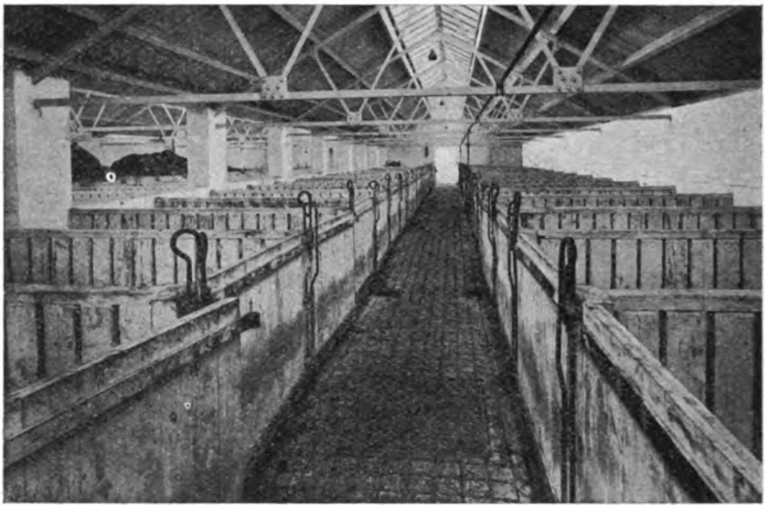


Fig. 18.

arteries. The carcase is stamped by the Veterinary Inspector, and is sent to the hanging room or chill room as the case may be. The caul fat, heart, and healthy livers, sweetbreads, brains, and such glands as are retained, are kept on the slaughter room tables until the day's killing is finished when they are removed. In passing through these rooms one will notice the provision that has been made for cleanliness. The walls are of white glazed bricks or tiles; the floors are all laid to facilitate washing

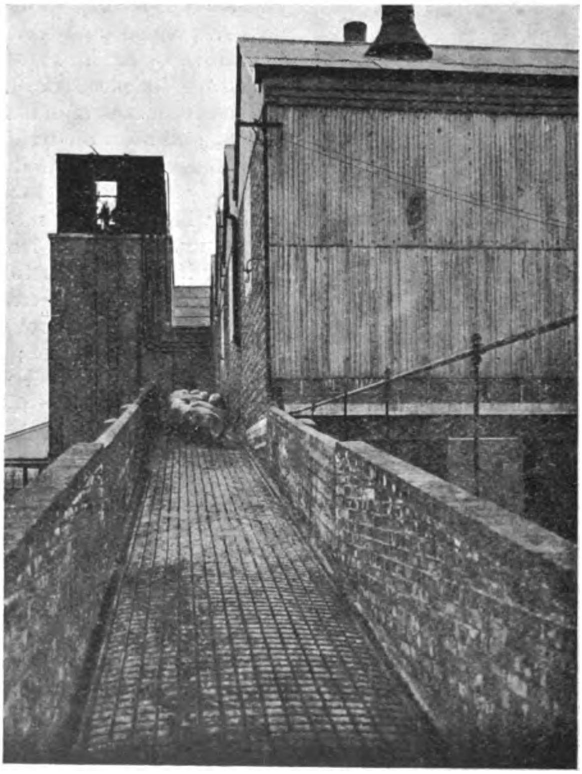


Fig. 19.

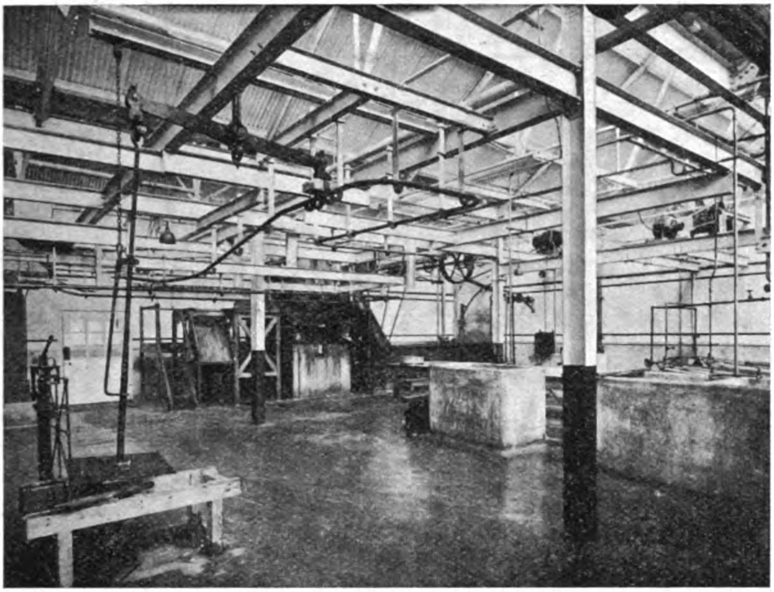


Fig. 20.

down; all corners are avoided and all angles are rounded; hot and cold water is laid on; the ventilation is perfect; and the meat hooks are of tinned steel.

If there were no other reason, public abattoirs could be justified as against private slaughterhouses by the manner in which the by-products can be utilised. This is not the place, nor is there time, to describe the various processes. Suffice it to say that it is by the utilisation of the by-products usually known as offals, that the freezing works and oversea abattoirs pay their expenses. In the ideal abattoir we are now mentally inspecting, the offals after veterinary inspection, and the edible portions have been picked out, are passed down different openings in the floor, as

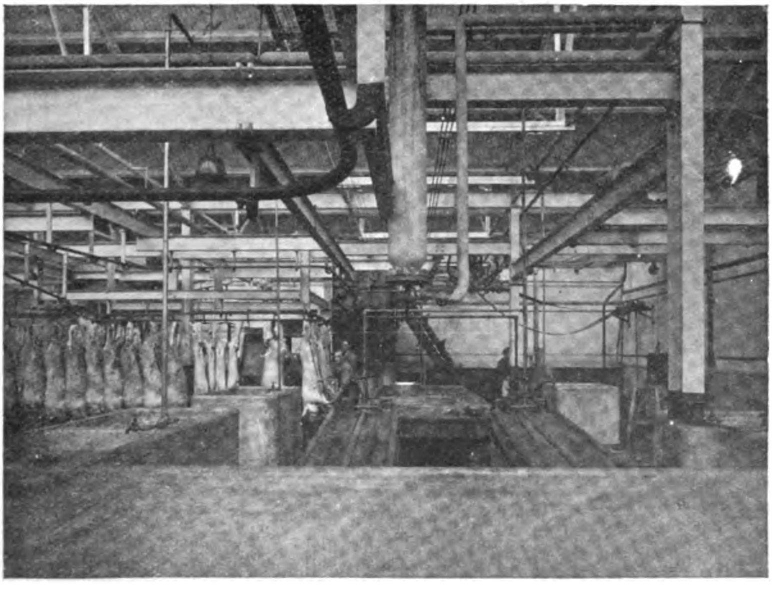


Fig. 21.

Fig. 22.

illustrated in Fig. 5, to the offal department on the floor below. This room is part of the unit, and is under the sole control of the butcher who has hired it. The inedible offals, which should be bought by the abattoir authorities to prevent their improper use elsewhere, are sorted over, the parts which have a commercial value are separated out, and the inedible residue is passed on to the by-product department to join that which came direct from the slaughter floor. This floor is in direct communication with the digester department and the offal is at once weighed and taken to it and treated by high pressure steam. The edible portions remaining on the ground floor are sold by the butcher and taken away by the various allied trades who deal with them in approved premises on the site.

The carcases of meat will be taken from the hanging or chill rooms direct to the butchers' cart for transport to his shop, or into the meat market. Behind each stall in the market is a chill room, so that in hot weather any meat unsold can be put back into cold storage, or bulk supplies can be kept in storage and sold from samples exhibited on the stalls of the market. Most butchers doing a high-class trade like

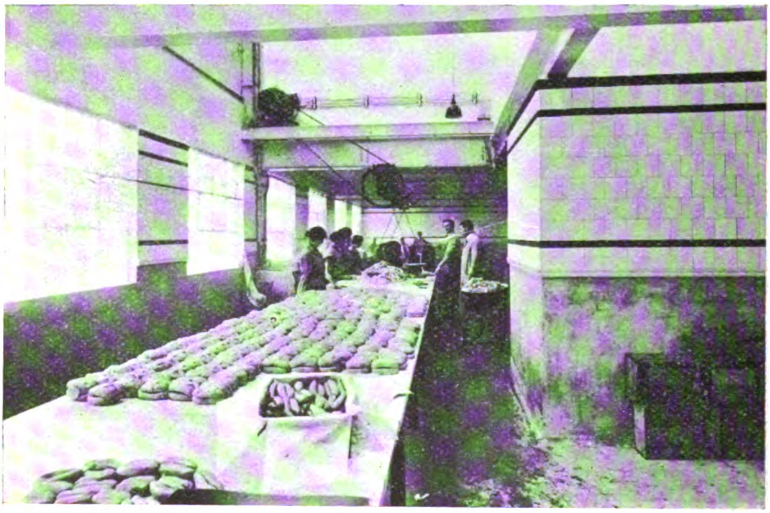


Fig. 23.

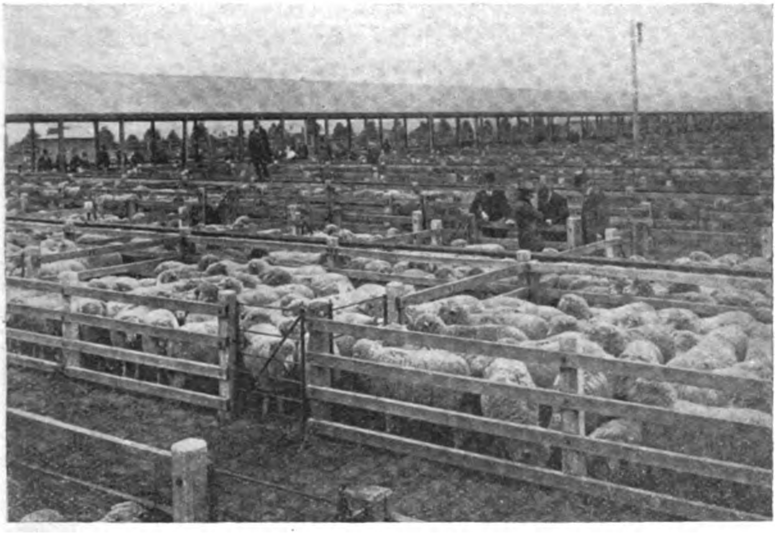


Fig. 24.

to keep their meat hanging in a temperature of 35°F. for any time up to 14 days to mature. This renders it more tender, juicy, and succulent than it would otherwise be.

The dead meat market itself will be lighted only from the North. It will be very simple architecturally because the money is wanted for more practical purposes, but will be designed for light and air, and above all, for the most perfect cleanliness and easy washing to walls, floors, and fittings. Indeed, cleanliness and sanitation must, and will be the keynote throughout the whole design.

The author has already remarked that it is impossible to expect people to be clean unless provision for cleanliness is made. In Australia and New Zealand, and, of course, in the other meat producing countries cleanliness is essential, and in Australia in particular no establishment is allowed by law to export meat until it is registered and, among a host of other things, provides separate location and apparatus for edible and inedible offal, exclusive lavatory and dressing accommodation for the meat inspectors, whilst for the employees they have to provide lavatory accommodation

Fig. 25.

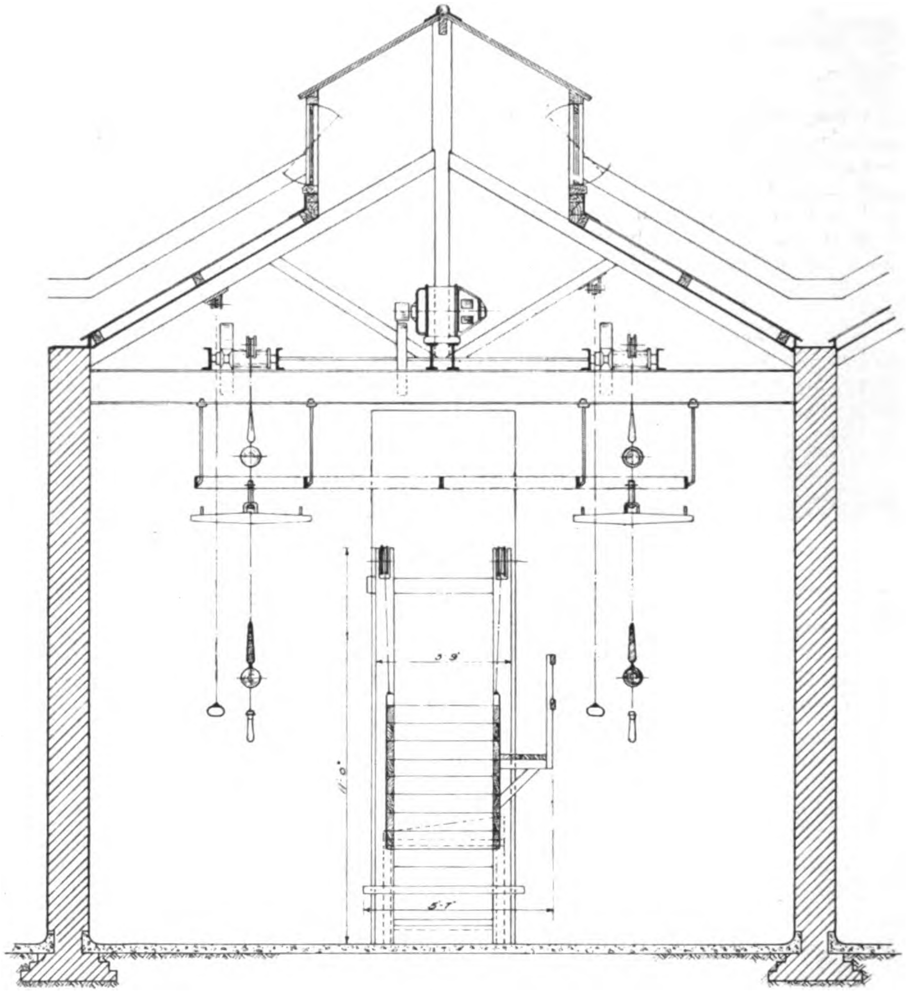


Fig. 26.

with wash-basins and shower baths, dressing rooms with accommodation for personal effects and clean and soiled clothing, and, last but not least, proper laundry and canteen accommodation, with food at reasonable prices.

The whole subject is so important and so interesting that the author hardly knows what to leave out, but at the risk of wearying his audience still further, he desires to make a few remarks on four subjects which are attracting a great deal of attention. These are the so called humane methods of killing; the Jewish method; veterinary inspection; and the responsibility which rests on the Ministry of Health and the Local Authority for the sanitary conditions of our meat supply.

Humane Slaughtering.

The various methods of slaughtering animals for food as practised in different countries, the different types of "humane" killers in use, and their effects on the animals, have been fully described in an able paper read before the Congress of the Royal Sanitary Institute at Folkestone, by Mr. E. J. Burndred, M.C., M.R.C.V.S., etc., Veterinary Inspector at Blackburn.

The author has already indicated that in his opinion the mere adoption of bye-law 9B of the Ministry of Health, making the use of a mechanically operated humane killer compulsory, will in itself be of little value in stopping preliminary distress to the animals. To illustrate this, he desires to read a report which has been furnished

to him of a visit to a London slaughter house made last August, where a "humane killer" had been in use since 1914. The report says :—

"The superintendent showed me over the place and pointed out to me his ideas on the slaughtering of cattle. I saw the humane killer being used to stun the beast, which was dragged in by a rope from an adjoining lairage. The gateway of the lairage was fully 10 to 12 feet wide, quite open, and allowed the beast to see from the stalls in to the slaughter floor. The beast, after being dragged in, was tied down to a ring fixed to the floor and then stunned. During this operation sides of beef were hanging on the rails near by and not five yards away was a partly flayed animal, whilst the floor was covered with blood. One had only to watch the animal being brought in to see the agitated state of the beast."

It is a matter for deep regret that it is only necessary to visit practically any slaughterhouse—those for the operation of which municipal authorities are directly responsible as well as the smaller establishments—to see the same picture every day. The pity is, that influenced by pictures of this sort, this question of humane killing is approached by so many people of influence and position purely out of sentiment and without any real knowledge of slaughtering methods. The error into which our humanitarian friends have fallen, and into which they have led the Ministry of Health to the intense exasperation of the practical butcher—who is generally just as humanitarian as any are—is, in thinking that in replacing the poleaxe by the humane killer, they have replaced cruelty by kindness, or at any rate, humanity. It must be admitted that the poleaxe can be a barbarous weapon, which may produce paralysis without unconsciousness, and if used by inexperienced persons may be driven into some part of the head other than the brain, thus causing very acute pain; but, like the Jews, the point they have lost sight of is that before they can apply their humane killer they have to secure the head of the animal, and that it is in the preliminary manhandling of the animal to get it into this position, that the cruelty, as has been pointed out, occurs.

Bye-law (8) of the model bye-laws of the Ministry of Health, reads :—

"Every person engaged in a slaughterhouse in driving or bringing any animal to the place of slaughter shall (*a*) avoid as far as practicable, driving or bringing the animal over any ground which is likely to cause the animal to slip or fall, and (*b*) adopt such methods and precautions as will prevent the infliction upon the animal of unnecessary suffering or pain."

Having devised this bye-law, which, incidentially, is impossible of adoption in any abattoir or slaughterhouse in England, the Ministry, with the humane killer in its mind, produced bye-law 10, which reads :—

Every occupier of a slaughterhouse and every servant of such occupier, and every other person employed upon the premises in the slaughtering of cattle shall, before proceeding to slaughter any bull, ox, cow, heifer, or steer, cause the head of such animal to be securely fastened in such a position as to enable such animal to be felled with as little pain or suffering as practicable and shall in the process of slaughtering any animal use such instruments and appliances and adopt such method of slaughtering and otherwise take such precautions as may be requisite to secure the infliction of as little pain or suffering as practicable."

Let anyone say, if he can, how the head of any bull, ox, cow, heifer, or steer, can be securely fastened in position without causing great mental distress to the animal, and please consider which method best meets the admirable spirit of the bye-laws and the R.S.P.C.A.—the English method of the slaughter ring, rope and winch, and the Ministry's suggestion of securely fastening the head in position, or the oversea method which has been described, where insensibility and death come to the animal all unexpected, all unseen. The butchers, small blame to them, will have nothing to do with that terribly dangerous inplement—a killer firing a free bullet—and so far as the author knows, a killer with a captive bolt has not yet been invented suitable for heavy stock.

The slaughtering trade is, in the author's opinion, as anxious as any other to avail itself of any improved method of conducting its business, and were it convinced that the mechanical killer would be advantageous either in method or on the condition of the carcase, it would not wait for bye-laws to be passed by Local Authorities before adopting its use. It is by no means certain, and at the Annual General Meeting of the National Veterinary Medical Association, held at Bath in August, 1922, the following resolution—which was transmitted through the Council from the Central Branch of that Association—was considered :—

"As there is a great diversity of opinion on the question of the humane slaughtering of animals intended for human food, and the

subsequent effect on the flesh of the various methods used, we suggest that a Government Committee of Enquiry be instituted to investigate the whole subject; the Committee to consist of members of all professions and trades interested."

This resolution received the support of that Meeting and it was resolved that it be sent to the Ministry of Health, the Council of the Royal College of Veterinary Surgeons, the Ministry of Agriculture, the Board of Agriculture for Scotland, and the Board of Agriculture and Technical Institute of Ireland.

This resolution was recommended to the Court of Common Council of the Corporation of London, by the Cattle Markets' Committee last year, and was endorsed by that body; also by the National Federation of Meat Trades. This is, of course, the only sensible course to take, and it is to be hoped that before any further bye-laws are adopted, or legislation passed, the Committee of Enquiry will be appointed by the Government.

The Jewish or Kosher Method of Slaughtering.

The Jewish law, if law it can be called, is presumably founded on a commandment similar to that given, with many other wise commandments, to the Children of Israel, and described in the 17th chapter of Leviticus—"That no blood shall be eaten." Consequently all flesh that is for Jewish consumption has to be free from blood. Their custom of slaughtering which, like many other customs founded on Divine command, appears to have surrounded tself with a good deal of dogma has grown up on the assumption that perfect bleeding cannot be attained unless the animals' throats are cut whilst they are alive *and conscious.* With the facilities that existed in the ancient days this was possibly the case, but the author is of opinion that, questions of religious feeling apart, an animal stunned and killed in the overseas method, will bleed better than a kosher killed animal, which usually bleeds when lying down, or only partially hoisted by one leg. While, of course, the importance of complete bleeding is a medical fact recognised by all civilised people of whatever faith, it is not an easy matter to cut the throat of an animal like a bullock, particulary when it is not too tame: consequently, precautions have to be taken by throwing the animal and holding its neck in such a position that it cannot move its head whilst the knife is being used. The author has put in the Appendix a detailed description of the principles which must be observed in the United States, but it may be said, briefly, that to attain this position the procedure is to cast the animal by fastening a rope to its legs and jerking them from under it, causing the poor unfortunate beast to fall violently to the floor, not uncommonly bruising its flesh and breaking some bones. Its head having been secured by another rope, it is held fast on the floor and then an iron muzzle is placed over its closed jaws. A wooden lever is inserted and rested between the horns, then with the leverage so given, two men force the head back, causing the neck to be stretched, and it is in this position that the Jewish slaughterman or "shocket" cuts its throat and allows the animal to bleed to death. The preliminary chain dragging and casting of the animal can be even more cruel than the method of pole-axing or of using the humane killer previously described. This method of slaughter is absolutely forbidden in Switzerland and Finland, and has been condemned as cruel by all competent authorities.

The Secretary of the Board of Deputies of British Jews, in answering some press criticisms recently, said—"The 'violent throwing' does not exist; the jerking away of the forelegs does not exist; the casting is not part of the Jewish method, but is a non-Jewish preliminary performed by the ordinary slaughtermen. All that the Jewish "shocket" or killer requires is that the throat of the animal shall be presented so as to enable a killing to be made with a single horizontal cut."

As an effort of casuistry this is all very well, but a visit to practically any slaughter-yard, where kosher beef is being killed, will reveal that, particularly with a wild animal, violent throwing, jerking, and casting do exist. They are not, of course, part of the Jewish ritual, but the Jewish ritual renders them necessary, and so to the mind of the ordinary man the Jewish ritual is responsible for them. The model bye-laws 9 and 9a, of the Ministry of Health, which deal with humane killing, exempt any members of the Jewish faith duly licensed by the Chief Rabbi as a slaughterer when engaged in the slaughtering of cattle *intended for the food of Jews* according to the Jewish method of slaughtering *if no unnecessary pain is inflicted.* The italics are the author's, who

quite realizes that this is a question of deep moment to orthodox Jews, but if it is of deep moment to them, then surely it devolves upon the many eminent leaders of the Faith who, he is sure, would not for a moment countenance any avoidable cruelty, to find the capital necessary to provide plant which will enable cattle to be put into, and secured in, a suitable position for having their throats cut without all this preliminary and undoubtedly cruel throwing, jerking, and casting.

As regards the actual pain of death, there is probably little real suffering to the animal when its throat is cut according to ritual—Dr. Feldman puts it at 3 seconds, Prof. Starling and Foster, at from 5-40 seconds duration—and such a plant should be comparatively easy to design, and if the bye-law was adopted would put kosher killing inside the law. It could not now occupy this position, because a great deal of the meat killed by the Jewish method is not intended for the food of Jews, and the preliminary throwing of the animal is inflicting unnecessary cruelty.

Mr. J. R. Hayhurst, M.R.C.V.S., D.V.S.M., has just introduced some improvements at Islington designed to soften the fall and remove the necessity of using the iron muzzle, but the animal is still killed on a floor already covered with blood and within sight of its dismembered mates. The Kosher method should be restricted to killing animals *intended for the food of Jews*, and it should, and under the bye-law would, be illegal for them to sell any of this meat to the general public. Mr. M. Myers, at a conference in this hall in December, 1911, stated that the Jewish method of killing was of importance to something over 200,000 citizens of this country. This is about one-half of one per cent. of the population; yet of the cattle killed at Islington alone 75 to 80 per cent. are killed by the Jewish method, while in New York 90 per cent. of the cattle and calves are koshered, and nearly 50 per cent. of the New York Markets carry kosher beef only. The reason, of course, is that so long as Kosher beef can be sold to Christians, it is more simple for the butcher to employ one method instead of two.

Can one wonder that the butchering trade deeply resents the implication that their methods are cruel, when the Jewish methods at present more cruel are exempted on religious grounds? So long as Jewish meat is not reserved for Jewish consumption, as the bye-law intended, it is useless for the London County Council or anyone else to adopt bye-laws enforcing the use of a humane killer as the butchers will simply kill Kosher. The Mr. Myers already quoted stated that a very considerable proportion of meat that Jewish butchers are not allowed to sell (on account of the animals being diseased) goes into the shops of Christian butchers and is consumed by their customers.

The 200,000 members of the Jewish faith may get well bled meat, but they are neglecting all scientific teaching if they fail to realise that they are also very frequently getting fevered meat. Mercifully, in the Overseas Dominions, except for local Jewish consumption, they will have nothing to do with this method. Of the 8,000 to 10,000 tons of meat sold in the London Central Markets every week, 85% of the beef and 93% of the mutton is imported and not kosher killed. This meat is, of course, largely used in the hotels and restaurants, where people of all faiths feed. A writer in the *Imperial Food Journal*, who knows his subject, says:—

"For it is the shambles of the ordinary British slaughteryard which is the root cause of more evil than anyone can properly estimate. The effect of bad dietary on a nation cannot be measured, and in the horrors of the straining tether and the goad stick that impel the agonized bullock to his execution in full sight of the carnage of his fellows, lie dangers that come to the consumer through fevered and tainted meat in a hundred public markets. There is no need to labour the point here. To deny its reality and consequence would be to sweep away overwhelming testimony, and the skilful butcher who, up and down the country, is minimising these handicaps by his personal efficiency, recognises that his industry has lagged behind all others as regards progress in modern equipment.

What a contrast between the home slaughterhouse and the abattoir of a meat works in the Southern Hemisphere! In all the vast herds that go innocently to their quick and painless doom in a modern meat works, there is not a tithe of the anguished fear and mad struggle to be found in a single slaughterhouse at home. Were it otherwise, Britain could not be served by a million tons of good sound meat annually, in stocks that successfully stand the voyage from the other side of the world.

The secret of the whole business lies in keeping the cattle ignorant of their fate until the instant of the blow that lays then unconscious, and the common sight of a peaceful cattle race, with

the animals standing tail to nose throughout the queue right up to the stunning pen proved that this terror has been banished from the Colonial abattoirs."

Veterinary Inspection.

In his presidential address to the Veterinary Inspectors at the Congress of the Royal Sanitary Institute, held at Folkestone recently, Major-General Sir Langton Blenkinsop, K.C.B., D.S.O., Director-General Army Veterinary Service, stated :—

"The influence of animals on the health and well-being of the nation cannot be treated lightly, and wherever this influence is felt the Veterinary Inspector should have no small voice. The wastage of child life due to bovine tuberculosis is well known, and you are able to appreciate the toll this disease takes of our milk and meat producing animals. The work now being done for the eradication of this disease amongst animals in America and on the Continent of Europe, should undoubtedly stimulate the Authorities in this country to take steps to clear our herds of this scourge."

The diseases met with in stock coming to abattoirs to be killed for human food include, beside tuberculosis, actinomycosis, abscesses, hydateds (common in the Colonies), fluke, gangrene, bruises, cancer and cysts, whilst never a week passes without anthrax being reported somewhere. The "Meat Trades Journal" in March last reported the finding of a carcase infected with anthrax in the Manchester slaughter-house, and during the week previous to this there were in Great Britain 15 outbreaks of anthrax, one of foot-and-mouth disease, 29 of sheep scab, and 41 of swine fever.

Our Medical Officers of Health and Veterinary Surgeons are not given a chance, because the existing laws appear to be totally inadequate. The Inspectors are too few in number to deal with private slaughter houses and the Municipalities will not build modern abattoirs.

It will hardly be credited that, as Professor Share Jones, D.V.Sc., F.R.C.V.S., etc., pointed out at the Bournemouth conference last year, the number of veterinary surgeons exclusively engaged in all the branches of public health work is less than 50, whilst in pre-war Germany over 1,100 were exclusively engaged in the care of the meat industry alone. He also stated that in the United States in 1919, 212,245 carcases of cattle, sheep, swine, and goats, and hundreds of thousands of parts and organs which were locally diseased were prevented from being sold for human consumption. The greater part of this material was put through the digesters or manure plant, and turned into commercial use.

Contrast this with England, where it is not very encouraging to read the statement of Mr. J. O. Powley, M.R.C.V.S., of the Ministry of Agriculture, who says in a paper on "The Incidence of Anthrax"—"How common an occurrence it is to meet cases where an animal suddenly taken ill (with anthrax) has had its throat cut when in extremis and the carcase dressed for human consumption."

In June, 1920, the Ministry of Health appointed a Departmental Committee on meat Inspection. This consisted of Dr. W. J. Howarth, the Medical Officer of Health of the Corporation of London, Dr. A. W. J. MacFadden, Chief Inspector of the Ministry of Health, and Mr. Thomas Parker, the Veterinary Inspector of Newcastle-upon-Tyne. They issued a very valuable report, in which, *inter alia*, attention was drawn to the lack of a sufficient number of skilled inspectors, and it was pointed out that the number of existing private slaughter-houses needs to be reduced in order to facilitate better inspection. Each abattoir should serve the widest possible area; should be provided with adequate facilities for transporting (both by road and rail) live stock and meat to and from the abattoirs, and should be administered in such a way that no preference or advantage is given to any trader or class of trader over any other. The report also recommended that regulations should be made requiring the use of cleanly methods in regard to the transit of meat by road and its removal from wholesale markets.

So far as can be ascertained, the Ministry are still sitting on the report, but their leaven works slowly.

In January, 1922, a conference of dealers in meat and other foodstuffs was called a the London Chamber of Commerce by the British Cold Storage and Ice Association to consider the possibility of introducing reforms into the inland transport of food stuffs, particularly meat. At this meeting Dr. Hanna, the Assistant Medical Officer of Health for Liverpool, and Lieut.-Col. T. Dunlop Young, Chief Inspector at the London Central Meat Stores, were absolutely in agreement on the necessity of urgent measures being taken. Captain Darling,

of Canada, stated that frozen meat imported from Canada loses more in 36 hours after its arrival at Liverpool than it does in the 12 days preceding its arrival.

Is it too much to ask on behalf of ourselves and our children and grandchildren that the Ministry of Health should be deserving of its high title and high office, and insist with no uncertain voice that our home-killed meat should be guaranteed free from disease; that our Municipalities, who justly pride themselves on Local Government, should build proper up-to-date abattoirs and exercise through their Medical Officers of Health and Veterinary Inspectors the power they already possess of seeing that the conditions under which meat is killed, prepared, transported, and exposed for sale shall be such that it will be impossible for it to be diseased, dirty, or contaminated? It can be done in the Overseas Dominions—why not here? Are they greater than we?

APPENDIX.

Metropolitan Abattoirs and Stock Markets.

Adelaide—South Australia.

The work done by the Board is as follows:—

The butcher buys his weekly requirements in the Stock Markets. On the fall of the hammer the Board's employees take charge of each butcher's stock, brand it and deliver it to the lairages attached to the slaughterhalls.

The Board holds the Butcher's Stock for a week free of charge, feeding it as required. If more than a week's supply is purchased by the butcher, the Board is prepared to hold it and feed it at a fixed price.

As the markets are only held once a week, the butcher has to buy enough to carry him on until the next market.

The stock are slaughtered according to the butcher's orders, inspected immediately after slaughter by trained Meat Inspectors, chilled, and then delivered in enclosed dust-proof insulated vehicles direct into the butchers' shops.

The Board's employees handle the carcases from the markets to the shop. This ensures perfectly clean, healthy and properly chilled meat being handled by the butchers, or, as they now are, "Meat Purveyors."

The whole of the edible portions of the by-products of offal are delivered to the butcher if required, but if any parts are not required the Board buys these from the butchers at agreed prices. The parts delivered to the butchers are tongues, hearts, livers (without the lights), brains of sheep, sweetbreads, ox and calves' feet and lambs' heads.

The intestines are purchased by the Board from the butchers. Butchers take their caul fats from cattle, but the Board purchases from the butchers all other fats at highest market rates.

Heads are purchased by the Board from the butchers.

The butchers, therefore, get the full value of the offals.

Tripes, ox and calves' feet, and calves' heads are scalded for the butchers.

The Board takes as part toll the blood of stocks, lungs, third stomach of large stock and contents of stomach and paunches of stock.

The Acts provide that the Board must render all by-products merchantable by means of dessicators, digesters, etc.

In addition to the slaughtering work done by the Board, a number of Inspectors are employed in supervising the butchers' shops in the area.

It is quite possible that after the meat is delivered from the works to the shops, it may become unfit for consumption or unclean through insanitary conditions existing at the shops, and it is the duty of the Inspectors to see that the shops are kept clean and that all small goods are manufactured under the best conditions.

The whole of the meat slaughtered at the works is delivered to the butchers' shops throughout the area in large motor lorries which are enclosed and insulated. The meat is hung on bars from the roof of the van—sheep and pigs whole (large pigs in halves) and large cattle in quarters.

A connecting bar from the lorry to the butcher's shop enables the meat to be delivered from the van into the shop without undue handling.

The charges are:—

Large Cattle ...	... 9/1	per head.
Sheep and Lambs	... 1/4	,, ,,
Pigs 15lbs. or under	... 1/6	,, ,,
,, up to 200lbs.	... 4/-	,, ,,
,, over 200lbs.	... 6/6	,, ,,
Calves up to 200lbs.	... 2/9	,, ,,

These charges cover handling from the markets, feeding for a week, slaughter, identification ticketing, inspection and chilling.

Delivery charges are 1¾d. for every 10lbs. or portion of 10lbs.

The total cost to the butcher for the work done by the Board is a little less than ½d. per lb. and the butcher is relieved of the whole of the slaughtering work with its attendant expenses and worry.

All the butcher has to do is to buy his stock in the markets and order it be killed as he requires it. The Board does the rest, even providing free the order books and envelopes for the butcher's use.

Notwithstanding the increased wages which had to be paid since the opening in 1913— over 30%—and the increased cost of stores of every kind, the Board has not increased its charges since the opening day.

This result has not been due to high fees, but to the operations of its by-products department, which practically provides the profits.

In this Department the Board treats the fats purchased from the butchers, making prime beef dripping (a large quantity of which is sold to the butchers at cost price) prime mutton tallow, No. 1 Mixed Tallow, bone manure, blood manure, poultry meat meal, bone grit and bone meal for poultry and meat meal for pigs.

All stock which are condemned by the Inspectors are conveyed to a separate establishment, being treated under high pressure steam and the result being a non-edible tallow and bone manure.

At this establishment are treated also the carcases of stock which die in the area.

The Board's Acts provide that all stock which die in the area or are killed in the area other than at the abattoirs must be brought to the abattoirs or be buried under the direction of an Inspector. This provision was inserted to do away with knackers' premises and to prevent diseased stock being fed to pigs.

The Board collects by means of motor lorries all these carcases, on notification, thereby relieving the owner of the necessity for handling the carcase.

Financially, the Metropolitan Abattoir and Stock Markets of Adelaide have been successful.

KOSHER KILLING.*

The Jewish law of slaughtering applies to animals and birds. This is entrusted only to people versed in the law and skilled in the work. The operation, however, cannot be done by a deaf mute, an idiot, a minor, by one who is intoxicated, nor by an old man whose hands tremble, for the reason that he may press the knife against the throat of the animal instead of moving it forward and backward, which is the prescribed method.

The length of the knife must be twice the width of the throat of the animal, the maximum being fourteen finger breadths. The knife must be sharp, smooth, and without any perceptible notch. It is examined before slaughtering, first being tested on the finger and then on the edge of the finger nail, on both sides of the knife. It must also be examined immediately after slaughtering and if a notch is found afterwards the animal is declared unfit for use. Before slaughtering a blessing must be pronounced to the Lord, as commanded. When many animals are slaughtered at the same time, one blessing is sufficient for the whole lot.

The act of slaughtering consists of cutting through the windpipe and the gullet. The principles which must be observed are as follows :—

1. There should be no delay by interruption while the slaughtering is being performed.

2. The knife should be kept in continuous motion forward and backward until the organs are cut through. A delay of a moment makes the animals unfit.

3. The knife must be drawn gently across the throat without any undue exertion on the part of the killer.

4. The killer has no right to lay a finger on the blade while killing, as the slightest pressure renders the animals unfit.

5. The knife must be drawn over the neck of the animal; if it is placed between the windpipe and the gullet or under the skin so that any part of the knife is not visible while the act is being performed, then the animal is unfit for food, even though the other actions may have been correctly executed.

6. The limits within which the knife may be inserted are from the large ring of the windpipe to the top of the upper lobe of the lungs when inflated. Slaughtering by the insertion of the knife in any part above or below these limits is called "slipping," and renders the animal unfit for food.

If either the windpipe or the gullet is torn out or removed from its regular position during slaughter, the animal is branded unfit for food. This is called "tearing." Soon after the slaughtering the killer must examine the throat of the animal and ascertain whether the windpipe and the gullet are cut through according to the requirements of the Jewish law.

*Extracted from "The Packers' Encyclopedia."

DISCUSSION.

THE CHAIRMAN, in proposing a hearty vote of thanks to the lecturer for the extraordinary pains he had taken in putting before the members a large number of ideas with regard to the humane treatment of animals on the occasion of their slaughter, said to him the matter was most interesting from the point of view of the methods adopted in the Southern Hemisphere. He had long felt that many steps ought to be taken in this country for the purpose of dealing with the home killing of our meat. At the Newcastle Conference of the Royal Sanitary Institute he had proposed a resolution, which had been carried unanimously, in favour of the abolition of private slaughter houses, of which there were 20,000 in this country to-day. That resolution had been endorsed at the Folkestone Conference and had been forwarded to the Ministry of Health, but no reply had yet been received. Why such a step was, in his opinion, so very necessary was that in the middle of the war Islington cattle market had been designated by the Ministry of Food for the purpose of slaughtering all animals

which had to be slaughtered within an area of twelve counties. Prior to the war something like 200 to 300 tons of meat had been condemned year by year as unfit for human consumption; but when the Islington cattle market had been appointed the sole market for the slaughter of animals within the twelve counties, that figure of 300 tons rose to between 1,600 and 2,000 tons. That showed at once that a large number of animals which were known to be diseased were, in ordinary circumstances, slaughtered in the various counties surrounding London, and the meat, not being under rigid inspection as it was at Islington, was distributed and sold for human food. If that had been the case within those twelve counties, one could imagine what it meant taking the whole of Great Britain from John O'Groats to Land's End. It would, therefore, be seen how very necessary it was to abolish private slaughter houses, and to put all meat intended for human consumption under rigid inspection. He could not urge too strongly the fact that all animals ought to be inspected ante-mortem and post-mortem.

Before arriving at the condition of things such as the author had described, private slaughter houses would first have to be abolished. That having been done, then he thought the municipalities throughout the country would have carefully to consider what steps they could take for the purpose of improving the methods of slaughter. We might not be able in every instance to adopt such a thorough system as the author had suggested, because this was an old country. The By-laws of the Ministry of Health also required consideration, as they did not seem to him to meet the case; in fact, the lecturer had shown that they did not.

The paper had put thoughts into their minds which they would take away with them and carefully consider and discuss with their friends, and thereby be the means of awakening public opinion and bringing about better methods of dealing with the slaughtering of animals.

The Right Hon. G. H. Roberts, M.P., agreed that there was great need of reform in regard to the slaughtering of animals. There was a very strong movement in the country in favour of that reform, but there was just a danger that that reform might move in the wrong direction. The paper should have a very salutary effect on certain endeavours which were about to be made to direct the attention of the House of Commons to the problem. First of all, everybody was concerned to see that meat reached the consumer in a healthful and proper fashion. Undoubtedly much that took place to-day tended to carcases being heated and not given immunity from disease. Therefore, a great deal more inspection was required.

He was being pressed, as other Members of Parliament were, to identify himself with a movement for making compulsory by Statute the use of certain humane killers. Most Britons were humane in instinct, and desired that the most humane methods should be adopted in the slaughtering of animals. Therefore, they were all instinctively inclined to identify themselves with any movement which claimed to have that purpose in view. But Members of Parliament were busy persons and, therefore, did not always very completely analyse proposals which were submitted to them. The underlying purpose was invariably the great attraction. Therefore, he was glad to have had the privilege of hearing the author's paper that afternoon, and also to have had the further advantage of having had conversations with Mr. Williams. The problem of the immunity of animals from cruelty in slaughtering was not, however, to be covered by the compulsory use of any form of humane killer. There was already evidence that there was danger in the use of certain humane killers which were being universally recommended, and, for his own part, whilst he was in favour of the slaughtering of the animals being conducted as humanely as possible, he wanted, before he gave his assent to the adoption by law of any particular method, to have the assurance that there was no injury possible to those who would be called upon to use those weapons. He did not think anybody was in a position to dogmatise on the subject, and, therefore, the conclusion which the author had reached was, he thought, a very wise one, namely, first of all that the principle should be accepted. Parenthetically he might say the author was perfectly correct in stating that there was no desire on the part of slaughtermen to act cruelly to the cattle which they had to kill. They were compelled to make the best use of the devices placed at their disposal. There was common agreement in the trade and outside it that avoidable cruelty ought to be avoided. That there was much cruelty was probably inevitable under present circumstances. Therefore, there should be a common purpose to be worked to of devising the best means of slaughtering which should obviate, or at any rate reduce, cruelty to a positive minimum. Agreement as to how that could best be secured had not yet been reached. For his own part he felt it was a much larger and more comprehensive matter than the adoption of a humane killer. It was the whole problem of the treatment and the transport of the animal from the point of grazing to the slaughter house, and thereafter to its being turned into meat. There was far more cruelty in bringing the animal to the point when a humane killer could be utilised than could ever be overcome by the adoption of any such device. It was only by taking a much broader view than many humanitarians were taking to-day

that the difficulty could be solved. He had worked with those humanitarians and had great admiration for the motives which inspired them, but he did not want them to seek to delude members of the public into the belief that they had found a panacea for the evil in the adoption of some simple device which attracted them for the time being. It was a huge problem which could only be dealt with on a broad comprehensive basis. Throughout the country properly built and well-equipped abattoirs should be provided, because, after all, it was not merely a question of striking the animal at the right point when it had been secured at a particular point. There was the anguish felt by an animal at being led into some of the private slaughter houses and seeing its disjointed mates hanging up, and to have the scent of blood assailing its nostrils. There was far more cruelty in that than there was in the use of a pole-axe, much as he deprecated the continuance of that form of device. So it was that the author had served a very useful purpose by his paper. If he, personally, was driven as a Member of the House of Commons to give his vote for or against what was described as a humane killer, then he would vote for it if there was no other method placed before him; but he at least would not be deluded into the belief that it solved the great problem of cruelty to animals which had to be slaughtered. He would then vote for it merely because he recognised that the great mass of the people only learned by positive demonstration. There were large masses of people deluded into the belief that cruelty was going to be eliminated in the slaughtering of animals by the adoption of a humane killer. He was convinced that the problem was bigger than that, and that it had to be approached from a larger and more responsible aspect.

Mr. Norman Graham (Hon. Secretary, Humane Slaughter of Animals Association) said he was in sympathy with what he had heard with regard to the improvement of conditions generally in slaughter houses, but he did not think quite fair notice had been taken of the humane killer. The last speaker had spoken of it as if it were something new, but it was nothing of the sort. It had been in practice for many years and had proved absolutely satisfactory. If a man was an expert with a pole-axe, the "punch" could be driven into the brain causing immediate anæsthesia of the animal; but if a man was not an expert, or if his nerve or strength failed, very great suffering and cruelty were caused to the animal. With regard to the learner, that was nearly always the case. With the use of the humane killer, the right-sized bullet was selected, the muzzle was placed against the right spot on the forehead, and the human element was eliminated altogether and instant death was always caused.

Mr. C. A. Knightbridge (Vice-President, National Federation of Meat Traders' Association) said the paper had opened up to him an entirely new vista, and it required a good deal of thought before one could dare to offer any considered opinion. There were several things which the meat trade were bound to value. They were bound to value their private slaughter houses. They were not altogether prepared to accept even the castigation of the author upon the conduct of private slaughter houses generally. He personally was bound to admit that he had not been into all the private slaughter houses in London, and he was perfectly certain the author had not, because he had not been in his (Mr. Knightbridge's) slaughter house. While some of the things mentioned in the paper might be true of some slaughter houses, it was not true of all. He had been particularly struck by the statement of the author's as to the length of time a carcase was hung in Australia for bleeding purposes. Even in private slaughter houses in this country a bullock was pole-axed and finished in less than half an hour, with only three men, or less, working on it. The trade had constantly been abused for refusing to adopt the humane killer, but the humane killer not only killed animals but human beings. Only as recently as the present week there had been a fatality in the country in connection with it. They as a trade contended that an instrument which fired a free bullet was not the sort of thing to use for killing cattle.

Councillor John D. Cuthbertson (General Secretary of Markets, Glasgow) said the Corporation of Glasgow had adopted in detail all the suggestions which the author had put forward in his paper. The Corporation of Glasgow had very little to learn from what the author had stated.

Mr. Walter Covell said while the City of Glasgow had learned nothing that afternoon, he might also say that his trade had not learned much. He supposed the one and only objection which the retail trade had to the abolition of the private slaughterhouse was that it considered that, by means of the private slaughter house, it was able to provide its customers with good and healthy meat at the least possible trouble to itself, and at the least possible expense to the consumer. Much had been heard about the cruelty which existed in private slaughter houses. He had had rather a wide experience of private slaughter houses in connection with his business, and he refused to believe that in any single instance was there cruelty—wanton or otherwise. He honestly believed that a pole-axe was as humane an instrument of slaughter as had yet been devised, and that the knife in the case of smaller animals was also as humane an instrument as could be devised. They as a trade were out for the most efficient way in which to work their business, and if any

method could be brought forward and proved by scientific demonstration to be more humane than the present method, it would be at once welcomed by the trade. There was not a single man in the trade who desired the continuation of the use of the present instrument if he could be convinced by scientific demonstration that a more merciful instrument could take its place; but it must not only be humane to the animal but safe to the operator.

MR. C. EMANUEL said the Jewish method of slaughtering had been somewhat criticised in the paper, but the Jews were the only people who really trained their slaughterers from the very commencement; and they did not train them on live animals. He believed they were the only people who inspected their meat both before and after killing. He was in complete sympathy with the author in his demand for public abattoirs. The Jews were not in favour of private abattoirs, although, curiously enough, some of their opponents, who were unscientific people, had suggested that the killing of meat for Jews should be confined to private abattoirs. The Jews resented that; they preferred full inspection. He gathered from the paper that the author was not actually a believer in what had been alleged to be the inhumanity of the Jewish method of slaughtering—which method consisted of a single cut with the sharpest possible knife wielded by a trained person of respectable character who had passed the requisite examinations. Two very eminent scientific gentlemen, reporting quite independently, had testified that the Jewish method of slaughter was absolutely humane. It was thought that the Jewish religion made it essential for the present method of casting to exist and continue. He absolutely denied that. He desired to emphasise that what the author thought was a cruel method of casting had been pronounced by scientists to be a humane method, which moreover would be improved until every one was satisfied about it. In the meantime he felt sure that the Jewish method, with its preliminaries, was absolutely humane.

THE CHAIRMAN then moved the following resolution: "As there is a great diversity of opinion on the question of the humane slaughtering of animals intended for human food, and the subsequent effect on the flesh by the various methods used, it is suggested that a Government Committee of Enquiry be instituted to investigate the whole subject, the Committee to consist of members of professions and trades interested."

MR. HAROLD NELSON seconded the resolution.

PROF. WOOLDRIDGE supported the resolution as being responsible for the drafting of it when it had first been brought before the National Veterinary Medical Association. He felt convinced that if it could be adopted by the meeting it would help very considerably in the setting up of an enquiry which could have nothing but good results. Everyone was agreed that if it was possible to improve methods of slaughtering it should be done.

MR. NORMAN GRAHAM pointed out that in 1904 a Commission had been appointed to investigate the whole matter. There were several leading veterinary surgeons on that body which, after a long investigation, recommended that no animal should be killed without previous stunning. The London County Council had also held a very searching investigation, and had decided to adopt the Ministry of Health's compulsory byelaw.

The resolution was then put and carried with one dissentient.

A vote of thanks to the author for his valuable paper was then carried unanimously.

THE AUTHOR, in acknowledging the vote, said with regard to the remarks of his friend from Glasgow, he had never yet found anything anywhere in which Scotland did not lead!

A hearty vote of thanks was then accorded to the Chairman for presiding.

THE CHAIRMAN, in reply, said he had taken the chair that day in order to show that the Corporation of London was always foremost in the field for the purpose of doing what it could for the humane slaughtering of cattle.

The proceedings then terminated.

GENERAL NOTES.

THE PANAMA CANAL.—Commercial traffic through the Panama Canal during 1922 exceeded that of any former year since the opening of the Canal in number of ships, tonnage and tons of cargo carried. The amount of tolls collected in 1922 was also a record. The following figures confirming this statement are abstracted from *The Panama Canal Record*:—

Calendar year.	No. of ships.	Panama Canal net. tonnage.	Tons of cargo.
[1] 1914 ...	350	1,284,293	1,758,625
[2] 1915 ...	1,154	3.902,592	4,893,422
1916 ...	1,217	3,817,704	4,774,822
1917 ...	1,960	6,217,054	7,443,610
1918 ...	2,070	6,409,886	7,284,159
1919 ...	2,133	6,943,087	7,477,945
1920 ...	2,814	10,378,265	11,236,119
1921 ...	2,783	11,435,811	10,707,005
1922 ...	2,997	12,992,573	13,710,556

[1] Canal opened to traffic August 15th, 1914.
[2] Canal closed approximately three months by slides.

Flax Experiments in South Africa.—Experiments are in progress in South Africa with a view to ascertaining the possibilities of flax production on a large scale. The decline in flax production in Russia and Ireland, it is understood, is the primary cause for the search for a new source of supply. An English expert has selected the western part of Cape Province as the most likely section in the Union for flax growing, and Russian seed has been distributed to a number of farmers for experimental purposes. The growth has been very satisfactory, and it is possible, writes the United States Trade Commissioner at Johannesburg, that these experiments will finally result in the opening up of a new field for South African agriculture.

Mexican Malvavisco Plant as Substitute for Jute.—The discovery of a new fibre known as malvavisco, which is said to be a substitute for jute, is announced by the Industrial Experiment Laboratory of the Mexican Department of Commerce and Industry. The malvavisco plant grows abundantly in the humid level lands near the rivers and at present is employed in Vera Cruz for making brooms. Prolonged experiments, writes the United States Assistant Trade Commissioner at Mexico City, have shown this plant to possess qualities similar to jute and the cost of extracting the fibre to be small. The fibre has a silky appearance and has been woven into cloth with excellent results.

Grass Cloth Industry at Swatow.—The ramie fibre grows in Szechwan Province of China, whence it is imported into Swatow via Hankow. Swatow's imports of this commodity amounted to 7,566,400 pounds in 1921. The fibre is converted into ramie thread and grass cloth, exports in 1921 of the latter amounting to 1,632,900 pounds and of the former 1,533,800 pounds. Grass cloth is sent chiefly to Korea, while the thread goes largely to Singapore, Siam, and the East Indies where it is used in making fishing nets and as cordage. In addition, reports the United States Consul at Swatow, there is a large local consumption of both articles in the Swatow district.

Flax Experiments in New South Wales.—Experiments are being made on a large scale in flax cultivation in the Invernell district of northern New South Wales, in an attempt to discover a crop that will resist drought. Furthermore, flax is free from attack by the rabbits which overrun this region, whereas wheat crops suffer severely from this pest. According to a report by the United States Consul at Sydney, the flaxseed is supplied by a firm interested in encouraging the industry under a guaranty that at least 10 acres will be planted by each person so experimenting. Growers are guaranteed 8 shillings per bushel for their seed.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

Monday, June 18. University of London, at the London School of Economics and Political Science, Haughton Street, W.C., 5 p.m. Prof. G. Cassal, "The Restoration of the Gold Standard."

Geographical Society, 135, New Bond Street, W., 8.30 p.m. Captain C. J. Morris, "The Gorge of the Arun."

Tuesday, June 19. Statistical Society, at the Royal Society of Arts, John Street, Adelphi, W.C., 5.15 p.m.

University of London, at St. Bartholomew's Hospital Medical College, West Smithfield, E.C., 5 p.m. Dr. A. Balfour, "Topical Hygiene." (Lecture III.)

Anthropological Institute, 50, Great Russell Street, W.C., 8.15 p.m. (1) Mr. De Barry Crawshay, "Exhibit of Eoliths from the South Ash Pit on the Kentish Chalk Plateau, and Stone Implements from Mesopotamia." (2) Mr. S. H. Warren, "The Paleolithic Succession of Stoke Newington."

Roman Studies, Society for the Promotion of, at the Society of Antiquaries, Burlington House, Piccadilly, W., 4.30 p.m. (1) Annual General Meeting. (2) Mr. G. H. Stevenson, "Some Reflections on the Teaching of Roman History."

Wednesday, June 20. University of London, University College, Gower Street, W.C., 6.15 p.m. Sir Josiah Stamp, "Economical and Statistical Aspects of a Capital Levy." (Lecture V.)

Meteorological Society, 49, Cromwell Road, S.W., 5 p.m.

Geological Society, Burlington House, Piccadilly, W., 5.30 p.m.

Microscopical Society, 20, Hanover Square, W., 8 p.m. Dr. J. A. Murray, Papers by Dr. J. E. Blomfield. (1) Witches' Brooms. (2) Tumours of Trees: Birch.

Constructive Birth Control and Racial Progress, Society for, Essex Hall, Strand, W.C., 8 p.m. Mr. J. Lort-Williams, "Birth Control as it interests me."

Thursday, June 21. University of London, at St. Bartholomew's Hospital Medical School, West Smithfield, E.C., 5 p.m. Dr. A. Balfour, "Tropical Hygiene." (Lecture IV.)

At the London School of Economics and Political Science, Houghton Street, W.C., 5 p.m. Prof. G. Cassal, "Devastation and Reconstruction in Europe."

Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.

Linnean Society, Burlington House, Piccadilly, W., 5 p.m.

Chemical Society, Burlington House, Piccadilly, W., 8 p.m. (1) Mr. O. R. Howell, "The constitution of the higher oxide of nickel." (2) Messrs. F. Allsop and J. Kenner, "The relationship of the tautomeric hydrogen theory to the theory of induced alternate polarities." (3) Mr. S. Sugden, "Electron valency theories and stereochemistry." (4) Messrs. W. A. Bone, D. M. Newitt, and D. T. A. Townend, "The relative influences of water vapour and hydrogen upon the combustion of carbon monoxide-air mixtures at high temperatures." (5) Mr. I. W. Wark, "Metallic hydroxy-acid complexes. Part I. Cuprilactates. (a) Metallic hydroxy-acid complexes. Part II. Cuprimalates, their formation, properties and composition." (6) Mr. S. Minovici, "Cholesterol and its role in the organism."

Friday, June 22. Physical Society, Imperial College of Science, South Kensington, S.W., 5 p.m.

Literature, Royal Society of, and Anglo-French Society, 2, Bloomsbury Square, W.C., 6.15 p.m. Mr. R. H. Soltau, "L'Oeuvre de Pascal et la Pensée Moderne."

Saturday, June 23. Sanitary Institute, Cambridge. Discussion on "The Grading of Milk." Visits in Afternoon to Dairy Farm producing certified milk and to Field Laboratories.

Journal of the Royal Society of Arts.

No. 3,683. VOL. LXXI.

FRIDAY, JUNE 22, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

FINANCIAL STATEMENT FOR 1922.

The following statement is published in this week's *Journal* in accordance with Sec. 40 of the Society's By-laws :—

INCOME AND EXPENDITURE ACCOUNT.

January 1st to December 31st, 1922.

Dr.

		£ s. d.	£ s. d.
To *Journal*, including Printing, Publishing and Advertisements		3,343 16 2	
,, Library and Bookbinding		82 6 11	
,, Medals :—			
Albert	21 12 6		
Society's	30 1 6		
		51 14 0	
,, Sections :—			
Dominions and Colonies	83 12 7		
Indian	125 14 11		
		209 7 6	
,, Cantor Lectures		143 2 0	
			3,830 6 7
,, Expenses of Examinations			8,793 11 4
,, House :—			
Rent, Rates, and Taxes		544 3 4	
Insurance, Gas, Coal, Expenses and Charges incidental to Meetings		563 9 4	
Repairs		172 12 10	
			1,280 5 6
,, Office Expenses :—			
Salaries, Wages, and Pensions		3,706 6 0	
Stationery and Office Printing		472 5 10	
Advertising		2 15 6	
Postages, Parcels, and Messengers' Fares		278 18 9	
			4,460 6 1
,, Committees :—			
General Expenses			49 7 4
,, Donation to Conjoint Board of Scientific Societies			21 0 0
,, Balance, being Excess of Income over Expenditure transferred to Capital Account (see Balance Sheet)			596 17 4
			19,031 14 2

Cr.

	£ s. d.	£ s. d.
By Subscriptions	6,448 17 0	
,, Life Compositions	549 7 0	
		6,998 4 0
,, Interest and Dividends on Society's Investments	338 17 3	
,, Ground Rents	381 9 10	
,, Interest, Dividends, and Ground Rents from Trust Funds for General Purposes	499 8 3	
Do. from Building and Endowment Funds	22 7 5	
		1,242 2 9
,, Sales, etc. :—		
Journal	247 7 9	
Do. Advertisements	427 6 8	
Cantor Lectures	16 2 9	
Leather Reports	2 13 9	
		693 10 11
,, Examination Fees and Advertisements in and Sale of Examination Papers		9,739 13 6
,, Charges for Expenses for the use of Meeting Room		301 18 0
,, Rent of Cellars		56 5 0
		19,031 14 2

TRUST INCOME AND EXPENDITURE ACCOUNTS.

Dr.

	£	s.	d.	£	s.	d
OWEN JONES MEMORIAL TRUST—						
To Balance, January 1st, 1922 ..	3	10	8			
„ Interest on Investments	15	13	4			
	19	4	0			
Less cost of Medals and Prizes	19	14	7		10	7
„ Balance forward				640	3	8
				£640	14	3

Cr.

	£	s.	d.	Trust Accumulations, Dec. 31st, 1922. £	s.	d.
JOHN STOCK TRUST—						
By Balance, January 1st, 1922 ..	28	16	3			
„ Interest on Investments......	3	10	2	32	6	5
NORTH LONDON EXHIBITION TRUST—						
„ Balance, January 1st, 1922 ..	47	19	5			
„ Interest on Investments	6	14	10	54	14	3
DR. ALDRED'S TRUST—						
„ Balance, January 1st, 1922 ..	36	15	2			
„ Interest on Investments	7	14	5	44	9	7
THOMAS HOWARD'S TRUST—						
„ Balance, January 1st, 1922 ..	63	12	2			
„ Interest on Investments	19	19	8	83	11	10
MULREADY TRUST—						
„ Balance, January 1st, 1922 ..	63	2	1			
„ Interest on Investments	5	5	4			
	68	7	5			
Less Prize awarded	20	0	0	48	7	5
DR. SWINEY'S TRUST—						
„ Balance, January 1st, 1922 ..	120	0	0			
„ Ground Rents (Income from) ..	180	0	0			
	300	0	0			
Less Transfer to the Society's Income and Expenditure Account	140	0	0	160	0	0
FRANCIS COBB TRUST—						
„ Balance, January 1st, 1922 ..	38	14	7			
„ Interest on Investments	8	18	10	47	13	5
LE NEVE FOSTER PRIZE TRUST—						
„ Balance, January 1st, 1922 ..	24	19	4			
„ Interest on Investments	5	16	0			
	30	15	4			
Less cost of Prize & Medal awarded	10	16	0	19	19	4
FOTHERGILL TRUST—						
„ Balance, January 1st, 1922 ..	48	19	5			
„ Interest on Investments	13	12	5	62	11	10
TRUEMAN WOOD LECTURE TRUST—						
„ Interest on Investments	32	14	8			
Less cost of Professor J. A. Fleming's Lecture (including printing)	32	14	8	–	–	–
„ BENJAMIN SHAW TRUST—						
„ Balance, January 1st, 1922 ..	9	9	8			
„ Interest on Investments	4	13	6			
	14	3	2			
Less cost of Sir T. Oliver's lecture	10	0	0	4	3	2
CANTOR TRUST—						
„ Interest on Investments	140	5	7			
„ Ground Rents (Income from) ..	141	0	0			
	281	5	7			
Less Transfer to Society's Income & Expenditure Account	281	5	7	–	–	–
DAVIS TRUST—						
„ Interest on Investments	78	2	8			
Less Transfer to Society's Income & Expenditure Account	78	2	8	–	–	–
SIR GEORGE BIRDWOOD MEMORIAL TRUST—						
„ Interest on Investments	36	15	0			
Less Cost of Sir T. Arnold's Lecture (including printing)	36	15	0	–	–	–
RUSSIAN EMBASSY PRIZE TRUST—						
„ Balance Jan. 1st, 1922	5	0	0			
„ Interest on Investments	5	0	0	10	0	0
DR. MANN TRUST—						
„ Balance January 1st, 1922	51	8	6			
„ Interest on Investments	51	8	6			
	102	17	0			
Less cost of Dr. Ormandy's lectures	30	0	0	72	17	0
				£640	14	3
1923—Jan. 1. By Balance brought forward				£640	3	8

BALANCE SHEET, December 31st, 1922.

Dr.

	£	s.	d.	£	s.	d.
To Capital Account—						
As on January 1st, 1922 ..	28,561	0	9			
Donations *re* Building Fund and Interest ..	42,410	6	4			
				70,971	7	1
Appreciation of Investments				295	8	0
„ Income and Expenditure Account Balance				596	17	4
				71,863	12	5
" Sundry Creditors				2,444	7	3
„ Bank Overdraft (Building Fund Account) ..				5,740	19	10
				80,048	19	6
„ Trust Funds :—						
Capital Account	16,899	7	5			
Accumulations under Trust Income and Expenditure Account	640	3	8			
„ Sundry Creditors........	7	5	6			
				17,546	16	7
				£97,595	16	1

Cr.

		£	s.	d.	£	s.	d.
By Freehold Premises:							
Purchase of 18–19, John Street		42,000	0	0			
Alterations, Conveyance, etc.	6,645 19 2						
Less Sales of Books, etc.	494 13 0						
		6,151	6	2			
					48,151	6	2
„ Books, Pictures, etc.					10,000	0	0
„ Investments (see schedule)					17,481	8	5
„ Subscriptions Outstanding					2,881	0	0
„ Sundry Debtors & Ground Rents outstanding					893	11	4
„ Paid on Account of 1923 Examinations					1,100	0	0
„ Cash at Bank on Current Account (*less* cash in transit)					99	2	9
					80,606	8	8
„ Trust Funds:							
Investments		16,899	7	5			
Ground Rents, etc.......		90	0	0			
					16,989	7	5
					£97,595	16	1

We have audited the above Accounts and Balance Sheet for 1922 *with the books, accounts and vouchers relating thereto, and certify them as being in accordance therewith. We have verified the Bank Balances and investments.*

KNOX, CROPPER & Co.,
Chartered Accountants.

Spencer House, South Place, E.C. 2.
14th June, 1923.

SCHEDULE OF THE SOCIETY'S INVESTMENTS.

(*as valued December,* 1922).

Ground-rents (amount invested)				£10,496	2	9
£217	0	0	Great Indian Peninsula Railway 4 per Cent. Guaranteed Debenture Stock	157	0	0
£500	0	0	New South Wales 4 per Cent. Stock	445	0	0
£500	0	0	Canada 3½ per Cent. Stock	430	0	0
£100	0	0	Queensland 4 per Cent. Stock	97	0	0
£530	10	1	New South Wales 3½ per Cent. Stock	514	11	0
£500	0	0	Natal 4 per Cent. Stock	445	0	0
£321	15	9	Metropolitan Water Board "B" Stock	209	3	0
£6	0	0	New River Company Shares	6	0	0
£3,408	14	6	India 3½ per Cent. Stock	2,181	11	8
£500	0	0	South Australia 4 per Cent. Stock	500	0	0
£2,000	0	0	War Loan 5 per Cent..	2,000	0	0
				£17,481	8	5

TRUST FUNDS INVESTMENTS SCHEDULE.

	£	s.	d.		£	s.	d.
Alfred Davies Bequest	£1,953	0	0	Great Indian Peninsula Railway 4 per cent. Guaranteed Debenture Stock	1,800	0	0
Mr. Swiney's Bequest	4,477	10	0	Ground-rents (amount expended)	£4,477	10	0
Mr. Cantor's Bequest	2,695	11	3	Do. do. do.	2,695	11	3
Mulready Trust	105	9	9	National 5 per cent. War Bond, 1927	109	10	1
Howard Trust	571	0	0	Metropolitan Railway 3½ per Cent. Stock	510	9	5
Owen Jones Trust	522	3	2	India 3 per cent. Stock	423	0	0
Mr. Cantor's Bequest	3,273	16	6	Do. do.			
	648	19	7	Bombay and Baroda Railway Guaranteed 3 per Cent. Stock	2,573	10	0
J. Murray and others, Building Fund	20	16	4	India 3½ per Cent. Stock	20	10	0
	38	11	0	5 per Cent. War Loan	54	18	0
Francis Cobb Trust	255	14	1	New South Wales 3½ per Cent. Stock 1930-50	250	0	0
Le Neve Foster Trust	105	11	7	3½ per Cent. War Loan	100	0	0
	42	2	1	5 do. do.	40	0	0
John Stock Trust	70	4	0	5 do. do.	100	0	0
Shaw Trust	93	12	0	5 do. do.	129	6	8
North London Exhibition Trust	134	17	0	5 do. do.	184	15	0
Fothergill Trust	272	7	6	5 do. do.	374	0	0
Aldred Trust	154	8	0	5 do. do.	210	17	6
Endowment Fund	394	7	0	5 do. do.	525	2	3
"Trueman Wood" Lecture Endowment Fund	654	15	7	National 5 per Cent. War Bonds 1928	654	18	0
Sir George Birdwood Memorial Fund	734	19	9	5 per Cent. War Loan	674	0	0
Russian Embassy Prize	100	0	0	5 do. do.	91	9	3
Mann Trust	1,028	9	2	5 do. do.	900	0	0
					£16,899	7	5

NOTICE.

ANNUAL GENERAL MEETING.

The Council hereby give notice that the One-hundred-and-Sixty-Ninth Annual General Meeting, for the purpose of receiving the Council's Report and the Financial Statement for 1922, and also for the election of Officers and new Fellows, will be held in accordance with the By-laws, on Wednesday, June 27th, at 4 p.m.

(By Order of the Council)

George Kenneth Menzies,
Secretary.

PROCEEDINGS OF THE SOCIETY.

DOMINIONS AND COLONIES AND INDIAN SECTIONS.

(Joint Meeting.)

Lord Askwith, K.C.B., K.C., D.C.L., Chairman of the Council, in the Chair.

The Chairman said that owing to the absence of Lord Emmott, who was to have presided, but had been obliged to go to Belgium, he had been called upon to take the Chair. It was only necessary, for the information of those who read the proceedings in all parts of the world, to state that the author of the paper about to be read, Sir Richard Redmayne, had been down many mines, had known many miners, had been a member of many Royal Commissions and Committees on Mining, had written many books on mining, had worked at mining in South Africa, in this country and probably in other portions of the world, and for twelve years was H.M. Chief Inspector of Mines. Therefore, he was acquainted in a very unusual way with matters connected with mining, and would be able to speak with authority upon the subject of the basic metals with which he was going to deal.

The following paper was read:—

A REVIEW OF THE BASE METAL INDUSTRY, WITH SPECIAL REFERENCE TO THE RESOURCES OF THE BRITISH EMPIRE.

By Sir Richard Redmayne, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., M.I.M.M., F.G.S.,

Chairman Governor, Imperial Resources Bureau.

After such an upheaval as the world witnessed during the period 1914-1918, it is meet that the nations of the earth should take stock of their positions and, indeed, the effect of the great world-war on industry has, for some time past, occupied the attention of economists, politicians, writers, and business men, and must, for years to come,

prove a fruitful ground of research for students of economics. So important indeed has the subject been considered by the Carnegie Endowment for International Peace that they have endowed and embarked upon an economic and social history of the world-war, several volumes of which have already appeared.

Under the heading of the "British Coal Mining Industry during the War" I have contributed a volume wherein I have endeavoured to determine the effect of the War on the coal mining industry.

The iron and steel trade naturally falls into a further distinct compartment of inquiry, which, I understand, will be dealt with by the able pen of Mr. W. T. Layton.

Another branch of the mining and metallurgical industries is that which relates to the non-ferrous metals, or that class of metals which are known as the "base" metals, as distinguished from the precious metals—gold, silver, platinum, etc., the treatment of which falls into a fourth and distinctly separate category.

The importance of the base metals to the nation, if not fully realised before, was brought strikingly to the notice of the public during the Great War. To mention only the commoner and more largely used of these metals, namely, copper, lead, zinc, tin and aluminium, all of these played a highly important part in the conduct of the war. Without an ample supply of them it would have been impossible to have prosecuted the War to a successful conclusion. Of the mineral products they were, in that respect, of an importance second only to coal and steel, which were of greater importance than silver or gold.

I propose this afternoon briefly reviewing the position in respect of the five base metals I have named, more particularly from the British Empire point of view.

The effect of the War was to create a period of intensified production of most of the metals necessary to the production of the machines of war, which meant, of course, that nearly all the commoner metals, and some not so common such as Tungsten (Wolfram), were involved, and were produced in ever-increasing quantities.

The sudden ending of the War found the world over-stocked with supplies of these commodities. The temporary expansion of trade which characterised the period succeeding the cessation of hostilities, up to February, 1920, allowed of the continuance of active mining in the case of the base metals as in that of other raw products, but the great demand ceased suddenly. The position then was that we were faced with large stocks of metals to dispose of. The demand fell off not because the world did not require these metals, but because the world was unable to buy them at a price which would be remunerative to the holders of the stocks, for, it must be remembered, these stocks were produced when wages and fuel costs were exceedingly high, and far in advance of the pre-war period; costs which are still in advance of pre-war rates. It is not possible, therefore, to produce these metals on a pre-war basis of cost. That costs of production, and consequently selling prices will gradually fall one can, I think, prophesy with safety, but probably not to a pre-war level, or, at any rate, if prices fell to that level they would not long remain at it. Economy in methods of mining and economy in extraction and refining are the objects to be aimed at with a view to righting the position.

It is probable that the two factors which have conduced more than any others to the decline in manufacturing power of industry are the temporarily exhausted purchasing power of the nations and the high price of fuel. But as the financial conditions of other countries improve, there will undoubtedly be an extension of markets and trade, and international trade especially, will be upon a sounder basis than it was immediately after the War when, although there was a period of great production, it was production at a high cost followed by the inevitable collapse.

I have pointed out that rates of wages and price of fuel are never likely to fall to a pre-war level. How then is an economic price for the base metals to be attained? High prices inevitably kill demand and direct attention to substitutes in those cases where substitutes are available for the purposes. The answer is, by research to discover means which shall lead to the reduction in the labour necessary to be employed and the reduction in the quantity of fuel necessary by reason of its more perfect combustion and possibly by the substitution of leaching for smelting processes, and, finally, by the prevention of waste in recovery of the ores from the earth.

Waste there is in the recovery of all mineral raw products, but the loss is, I venture to say, greater in respect of the base metals

than it is in the case of coal, and probably of iron; for what percentage of the metal contained in the earth's crust actually reaches the manufacturing industries? Only that ore which it pays to mine—the richer ore—reaches the surface, the poorer adjacent ore being frequently left below irrecoverable by future generations. Then there is the loss in the dressing—the concentration—of the ore; and, finally, the loss in extraction. An interesting investigation might be carried out with the object of determining the probable percentages of the respective metals lost to mankind. It is a somewhat startling fact that the supply of certain of the base metals will be exhausted long before either coal or iron cease to be produced.

COPPER.

Copper, which figures so largely in the base metal industries, is the metal as to which the British Empire is worst off in point of domestic supplies.

The average annual world's output of copper at the beginning of the Nineteenth Century was only about 9,000 tons; by the middle of the century it had grown to 40,000 tons, and at the end of the century to over half-a-million tons. In 1913 it was nearly one million tons, and in the record year of 1917 it had amounted to one million and a half tons.

The world's production of ore in terms of metal is given in Table I. of the Appendix to this paper, the figures being in long tons (that is, long ton = 2,240 lb.) for the years 1913, 1917, 1919, 1920 and 1921.

In the year 1919, the British Empire contributed only 6 per cent. to the world's output of copper; in 1920 7½ per cent. and in 1921 8½ per cent.

The country chiefly affected by the decline in production since 1917 is, of course, the United States of America, for she produces normally over 50 per cent. of the total world's output, and large as is her proportion of the world's production, she controls a still larger production by ownership of mines in other countries, notably Chile and Peru.

The British Empire, with Canada and Australia as the chief producers, does not supply sufficient copper for her needs, nor even for the needs of the United Kingdom alone. Thus, the pre-war consumption (1913) of the three greatest copper consumers in the world was as follows:—

U.S.A.	340,000 tons.
Germany	255,000 „
Great Britain	138,000 „

or, in the case of Great Britain, one and a half times the Empire's output.

The great increase in the world's production and consumption of copper is chiefly due to the vast expansion in the use of electricity for power and lighting purposes which has characterised the last 25 years. Indeed, the importance of the metal in modern industry is shown by the fact that the motor car trade in the United States alone consumed 50,000 tons of copper in 1922.

From the point of view of potential resources the British Empire contains extensive areas of copper-bearing ground which might, with advantage, be subjected to close investigation with a view to increasing the output of that metal.

From this Empire point of view Canada presents the most likely source of increased supply, particularly British Columbia. It is reported that millions of tons of copper ore have been proved in Northern Manitoba where development has been active for several years.

The production from the Otavi mines in South West Africa is also increasing, and production may soon be expected on a larger scale from Papua, where are extensive deposits of high-grade ore.

The deposits of the Union Minière du Haut Katanga in the Belgian Congo are largely controlled by British capital. Hitherto the production from these mines has been hampered by length and cost of transport, but these difficulties are gradually being overcome and the production, which in 1921 was about 30,000 tons, is increasing rapidly, being over 40,000 tons in 1922.

The chief hope for the more economic treatment, and consequently gradual lowering of the price of the metal, would appear to be in the wider application of flotation methods in concentration of the ore and new leaching processes for the extraction of the metal from the ore, permitting as they do large deposits of low-grade ore to be worked. For instance, in Chile, the Chuquicamata and Teniente mines are examples of vast low-grade deposits, necessitating the handling of enormous tonnage at low mining and treatment costs.

In this connexion one may mention the deposits of Northern Rhodesia. Thus, the Bwana M'Kubwa Copper Company estimate that they have proved the existence of over

seven million tons of copper ore carrying an average of 4 per cent. of the metal, and they propose to apply a special ammonia process in treating the ore.

The treatment of low-grade oxidised copper-ores by leaching processes has developed greatly in recent years. In order that a leaching process may be successful the copper minerals must be soluble, or capable of being made so by a cheap roasting or other process, and the solvent employed must not act on the gangue associated with the copper mineral. Hitherto the most generally employed solvents for oxidised copper-ores have been sulphuric acid and ammonia.

In 1920, the leaching plant at Lake Linden, in the Lake Superior region, treating tailings of native-copper ore crushed to 28-mesh, made about 11 million pounds of copper at a cost of less than six cents per pound up to smelting, the recovery being over 80 per cent.

There are several well-known processes of leaching with sulphuric acid now in operation, which differ mainly in the method of recovering the copper in solution.

In some, the copper is precipitated by scrap iron, in others, as at Chuquicamata in Chile, where no less than 15,000 tons of ore containing brochantite, chalcanthite and atacamite are treated daily, by electrolysis. The extraction in February, 1921, was 94.15 per cent., treating ore averaging less than 2 per cent. copper. The New Cornelia Company in Arizona precipitates the copper by both methods. The Chino Company, in New Mexico, has recently adopted a method of precipitation by sponge iron, the finely divided copper being recovered from the material by froth flotation.

Leaching is not well suited to treatment of slimes.

It is not possible to generalise as to the process best adapted to the treatment of oxidised copper-ores, as no one process is economically applicable to all types of ores. New processes are constantly being developed and attention may be drawn to the large amount of work which has been done in recent years with the object of perfecting a process in which sulphurous acid may be employed as the solvent.

A fact worth noting in respect of the world's copper position is that the great Anaconda Copper Mining Company has gradually acquired the control of a considerable portion of the world's copper production. It recently secured the control of the Chuquicamata mine already referred to. It also controls the Andes mine, and several other important copper mines in Chile and elsewhere.

Incidentally, it may be mentioned that the Chuquicamata mine bids fair to become the greatest copper mine in the world. In 1914 the reserves of ore were estimated at 200 million tons, averaging over two per cent. copper. By the end of that year, an extra million tons were added, and by the end of 1916, 400 million tons more, making 700 million tons, which is equivalent to 14 million tons of metallic copper.

As to the immediate outlook in respect of copper, the outstanding feature has been the marked reduction in American stocks of this metal, which have fallen from about 530,000 short tons at the end of 1921, to a normal figure of about 290,000 tons at the end of 1922, probably due to the fact that war scrap has gradually been absorbed. It is probably safe to assume that the recent increased consumption is due to the fall in price, enabling copper to displace some of the substitutes which had come into use, to some extent, owing to the high price of copper.

It is noticeable that whilst American stocks have been reduced by about 50 per cent. during 1922, the refinery production nearly doubled; thus, whilst for January, 1922, the refinery output was about 40,000 short tons, for January, 1923, it was about 70,000 tons.

It will be remembered that the record refinery output of the United States was reached in the year 1918, with 1,216,000 short tons. The refinery output is now at a rate equivalent to about 850,000 short tons of copper a year. This, of course, includes copper refined from imported metal.

Lead.

The world's production of lead ore, expressed in terms of metal (long tons) for the years 1913, 1917, 1919, 1920, and 1921, was as shown in the table in the Appendix.

The British Empire is in a somewhat better position in respect of lead than as regards copper. Taking the years 1919, 1920, and 1921, the Empire produced respectively, 17½, 12½ and 24 per cent. of the world's production. The United States, Spain and Mexico are the greatest producers in the world.

But the amount produced within the Empire falls short of the amount imported

into the United Kingdom. There is imported annually into the United Kingdom something over 200,000 tons of lead in one form or another, but she exports a certain proportion of this, either as pig lead or manufactures of lead, to the extent of between 70,000 and 80,000 tons.

Before the War, Germany used to obtain from her own mines about 50 per cent. of the lead smelted in that country; the balance she drew from Australia and Mexico—largely from Australia in the form of concentrates, but the increase in smelting capacity in Australia during the War must materially affect the present position in this and other respects.

Whereas in the case of the ores of several of the metals over-development of ore deposits resulted from the exigencies of the War, the case of lead is somewhat different from that, say, of copper and zinc, for, although there was a marked increase in production resulting from the war demands, the increased production was attained at the sacrifice of high-grade ore-reserves rather than by extensions in smelting works.

From all one can learn it would appear that the lead-mining industry is exceptional in being one of the few branches of the base-metal mining industries which is not over-developed. It is remarkable also, that no great discoveries of lead ore have been made within recent years, and it looks as if the developed resources were being exploited near to, if not up to, their full capacity. Although we are far from meeting our requirements in lead, the Port Pirie lead smelting works of the Broken Hill Associated Smelters Proprietary, Limited, in Australia, (the largest works of the kind in the world) is capable, when working to full capacity, of producing 200,000 tons of pig lead and 8 to 12 million ounces of silver per annum.

The United States is the largest producer of lead in the world. It is also the greatest consumer of that metal. Spain and Australia both export more lead than America.

Taking the last pre-war year, we find that 82 per cent. of the world's production was derived from five countries, viz., the United States of America, which accounted for 37 per cent.; Australia, 20 per cent.; Spain, 15 per cent.; Germany, 6 per cent.; and Mexico, 5 per cent.

Recently, the output from Australia was reduced owing to labour troubles. The high price of materials reduced the output from Spain, and the transference to Poland of nearly all the lead mines of Upper Silesia has considerably reduced Germany's output. The output from Burma, on the other hand, has increased, and is likely to continue to do so.

Lead enters into a vast number of industries. It is, however, chiefly consumed in the making of white-lead paint, pipes and sheets, coverings of cables, and as an alloy with antimony and tin. It is also used largely for storage batteries, in enamel, glass, pottery, etc.,

Britain is the largest importer of lead in the world.

Before the War, Spain supplied 38 per cent. of our requirements; Australia 28 per cent.; U.S.A. 15 per cent. and Mexico 10 per cent.

The perfecting of the flotation process of concentration has had the effect of rendering possible the re-treatment of considerable accumulations of zinc-and-lead-bearing tailings and residues at the Broken Hill Mines of New South Wales.

Before the War, a total loss of five per cent. in smelting lead concentrate was considered good practice with a fairly good equipment. Of course, in smelting low-grade concentrates or slags containing lead, which had to be resorted to during the War, particularly on the Continent, the losses were much greater. The loss in smelting Serbian slag containing 8.5 per cent. lead was as high as 24 per cent. I merely mention these facts as pointing to the scope still remaining for research work.

Our resources of lead, within the Empire, are considerable. Burma alone should contribute greatly in future to the British requirements in this respect, and, looking to potentialities at home, I am one of those who believe that our own supplies will be found to be well worth further exploitation as foreign costs increase. It was the more cheaply worked deposits of Spain which originally rendered unprofitable the lead-mining industry at home, but since the day when lead-mining was extensively prosecuted in this country, methods of extraction have greatly improved.

I have stated that lead *mining* was not over-developed during the War, but this is not to say that a greatly increased output of ore was not obtained. There was a great increase drawn from reserves, and the close of the War saw smelting works with large stocks on hand, and down to March, 1922, the outlook for the industry was the reverse of cheering. Thereafter, the demand increased, and prices, with little exception,

rose steadily, probably due to the fact that three great lead consuming industries became active at the same time, viz., paint, storage batteries, and cables.

Industry is very active in the United States of America, and credible observers consider that during the present year that country will consume more lead than it produces.

Galena—lead ore—is the chief source of silver, and the position of the precious metal in point of demand, and consequently of price, must have an important bearing on the value of lead.

Zinc.

The ores of zinc are closely associated with those of lead, and the two metals are in many cases obtained from the same mine. Just as in the case of lead, the United States of America far exceeds any other country in the quantity of zinc she produces.

The table shown in the Appendix gives the production of zinc from the countries contributing to the world's supply for the years 1913, 1917, 1919, 1920 and 1921.

Taking the years 1919, 1920, 1921, the contribution of the British Empire to the zinc production of the world was 11 per cent, 6 per cent. and 30 per cent. respectively, of the world's production, the low figure for 1920 being due primarily to the strike at the Broken Hill Mines in Australia.

In point of consumption, taking the year 1913 as a normal year, the position stood thus :

United States absorbed	..	308,000	tons
Germany ,,	..	228,000	,,
United Kingdom ,,	..	191,000	,,

Those three countries are the chief consumers of the metal. The British Empire meets only one-third of the requirements of the Mother Country.

The use of zinc in commerce has grown rapidly. Formerly its use was practically restricted to the manufacture of alloys with copper, tin, and lead, but the realisation of its value as a coating material and the discovery of the galvanising process gave an enormous impetus to the consumption of zinc, and probably 65 per cent. of the total zinc smelted is consumed in this way. But there are numerous other uses to which it is put, one of the most recent being in the form of an alloy with aluminium in the manufacture of aeroplane parts and shell fuses.

The two most noticeable features in respect of zinc at the present time are :—

(1) The rising production of electrolytic zinc, notably in Tasmania, Canada, and the United States of America ; and

(2) The fact that, as a result of the War, the world's smelting capacity of zinc is largely in excess of the ore-production. The capacity in this respect of the United States of America alone is now 800,000 tons per annum.

As Mr. Gilbert Rigg has informed us in his interesting article, "The Zinc Industry at the close of 1919," prior to the War, there was, for all practical purposes, but one method of extracting zinc from its ores, namely, the distillation process. "The possibilities," he said, "of leaching and electrolysis had been "discussed and tried out more than a quarter "of a century, but in spite of numerous "attempts ranging in scale from laboratory "experiments to more ambitious efforts "reaching in at least one case to very large "expenditure indeed, the effect upon the "industry was so small as to be negligible."

The electrolytic process is now an acknowledged commercial success, although still the greater part of the production is due to distillation.

As illustrating the headway made by the electrolytic process of recovery one may point to the potential production of electrolytic zinc from the following well-known concerns :—

Anaconda Copper Mining Co., Great Falls, Montana, 55,000 to 60,000 tons. (This Company recently acquired the American Brass Company, and will require more than this quantity of zinc for its own consumption.)

Electrolytic Zinc Co., Risdon, Tasmania, 40,000 to 60,000 tons.

Consolidated Mining and Smelting Co., Trail, B.C., 20,000 to 25,000 tons.

Judge Mining and Smelting Co., Park City, Utah, 2,500 tons.

Brunner Mond & Co., England, 1,700 tons.

Interesting figures are available as to the actual output of electrolytic zinc from the Risdon works :—

Periods ended.			Output zinc (long tons).
Dec. 14,	1921	..	381
Jan. 11,	1922	..	1,238
Feb. 8,	,,	..	1,457
April 5,	,,	..	1,581
May 3,	,,	..	1,686
May 31,	,,	..	1,825
June 28,	,,	..	1,981
July 26,	,,	..	1,965
Aug. 23,	,,	..	1,943
Oct. 18,	,,	..	3,995
Nov. 15,	,,	..	1,975

Dec.	13, ,,	..	2,027
Jan.	10, 1923	..	2,009
Feb.	7, ,,	..	2,340

It would certainly seem as if electrolytic extraction will gradually supersede the distillation process with resultant saving in cost.

Black, indeed, was the outlook for zinc two years ago; there was little market and nearly all the home smelting-plants were shut down. By the end of 1922 the position had materially improved. In America, for instance, the metal had nearly doubled in price, and there were barely two weeks' supplies in stock, thousands of tons having gone to Europe to meet the increased demand. In 1921, the production was less than half that of what may be described as a "normal" year (*e.g.*, 1913). Zinc with copper constitutes the alloy we know as brass. Improvement in the engineering trades means an increase in the demand for zinc. Production in the present year is not likely to exceed consumption, stocks have greatly diminished, and the engineering trades are slowly improving. A recovery from the last two and a half years' depression would appear to be in sight.

Tin.

The Empire position in respect of tin is different from that of the three previously named metals, inasmuch as the Empire is the chief contributor to the world's production, accounting for more than half of the annual output. The Malay States are the chief producer, contributing over 36 per cent. of the world's output; then follow Bolivia and the Dutch East Indies, with about 20 and 15 per cent. respectively. (See Table in Appendix).

At present the consumption and production of tin appear about to balance, a feature which may be contrasted with copper where during the last two or three years drastic curtailment of output was resorted to. Normally, the United Kingdom imports about 35,000 tons of tin ore, about 8,000 tons of which are from British Possessions, and 40,000 tons of metal which, with the exception of two or three thousand tons, is derived from British Possessions. She re-exports, in a normal year, about 3,000 tons of ore, and 40,000 tons of unwrought tin. The balance, about 32,000 tons of tin ore, together with the domestic production which, in 1913—I take this as being the last normal year—was 8,355 tons, was apparently sufficient to meet the domestic requirements of the United Kingdom. In other words, the British Empire produced considerably more tin than was necessary to meet Empire requirements, the exports being chiefly to foreign countries.

Tin is peculiar in that its sources are few and far between, and few new deposits have been discovered in recent years, although it appears probable that the Belgian Congo will become an important producer in the not far distant future. It would seem that, unless really extensive deposits are yet remaining to be discovered, tin will be one of the first of the base metals to be exhausted, and, so far as I am aware, no satisfactory, or, at any rate, cheaper substitute than tin as a covering medium in "tinplates" has as yet been found, and in the manufacture of tin plates lies the chief consumption of tin. For the purposes of cooking utensils aluminium will probably take the place of tin, copper, and brass.

Tin is of importance in the making of certain alloys, *e.g.*, bronze, fusible metal, pewter, Babbitt metal and type metal.

The smelting of tin ore is concentrated in few hands, although the tin smelting capacity of the world is well in excess of the annual supplies of ore. In this respect the Straits Settlements heads the list, with a capacity of about 58,000 tons, Great Britain coming second, with a capacity of about 34,000 tons and the United States of America third, with a capacity of 30,000 tons. These figures are in terms of metal, the total world smelting capacity being about 175,000 tons per annum.

It appears that the Williams Harvey Corporation, in which the National Lead Company own one-third interest, is operating successfully in the United States, but that the American Smelting and Refining Company (Guggenheims) have difficulty in obtaining supplies. The National Lead Company consumes 10,000 tons of tin per annum and has acquired a large interest in the Llallagua mines in Bolivia, which are the largest individual producers.

Smelter production of tin in the United States has developed considerably of late years. Thus, whereas, in 1916, the output of smelted tin in that country was 2,261 short tons, in 1917 it was 6,065 and in succeeding years as follows:—

1918	..	10,284
1919	..	12,236
1920	..	17,652
1921	..	11,542

An interesting feature of the tin situation is that costs have been brought down to a point where the industry will be in a healthy condition as soon as more normal consumption is reached.

Aluminium.

Although aluminium, in the form of the silicate, is perhaps the most plentiful metalliferous mineral in the world, owing to difficulty of extraction, it is only of late years that it has come to be used commercially on a large scale. Although, too, during the war period the Central Powers, being short of supplies of bauxite, were forced by pressure of circumstances to endeavour to extract aluminium from clays, this is not yet a normal commercial possibility.

Bauxite, which contains from 30 to 60 per cent. of alumina, is the chief source of the metal, but only the comparatively pure mineral can as yet be used profitably for extraction of the metal.

The uses to which aluminium is put are very numerous, largely owing to its lightness and resistance to oxidation. It forms alloys with several other metals; is used in the construction of aeroplanes and airships, in telegraphy and telephony; in the manufacture of explosives, and in many other directions. If a process could be discovered whereby aluminium could be applied to the coating of iron its use would probably be vastly extended.

In 1913 the British Empire accounted for little over 1 per cent. of the world's production of bauxite.

In 1917	do.	do.	2 per cent.
In 1920	do.	do.	5 „ „
In 1921	do.	do.	9 „ „

The increase in the contribution from the British Empire is due to the development of the deposits in British Guiana, as a glance at the production table in the Appendix will show.

The United States of America is the chief producer of bauxite, contributing 43 per cent. (1921) of the world's output.

France comes next with 25 per cent. (1921).

A deposit of high-grade bauxite is not a commercial proposition unless the mineral can be mined and shipped at cheap rates to the smelting locality. For the actual production of the metal water-power is desirable and is usually employed. Thus, though bauxite is not mined in Canada, the cheap water-power available at Shawinigan Falls, Quebec, makes it profitable to extract aluminium from imported ore.

Besides the deposits of British Guiana there exist rich deposits of bauxite in India and the Gold Coast. In the former case their development will depend on local demand, small at present, for the metal, and in the latter case difficulties stand in the way of the transportation of the ore to a place convenient for its reduction.

Conclusion.

In the course of this survey I have referred only to five of the base metals. Time does not permit of my making the review complete. As to the general outlook in the base metal industry in the more or less immediate future, it would appear that stocks of the metals are being absorbed, demand is increasing and a gradual improvement might be foretold with reasonable certainty. There is a general feeling that we are on the eve of better times, a feeling which might be translated into certainty were the United States of America to cease from erecting tariff walls against foreign manufactured articles, and France and Germany were to settle their difficulties. It is difficult to see what ultimate financial benefit will accrue to either America or France as the outcome of their recent actions. Certainly, one effect of the Fordney Tariff must be to compel us to seek new sources of supply of raw materials and to develop markets in other parts of the world.

In conclusion, I should like to say that if I have been successful in interesting my audience in the subject I have dealt with, and that that interest results in evoking a discussion from the eminent experts present, I shall feel I have not failed in accomplishing the object I set out to attain.

APPENDIX.

World's Production of Copper Ore in Terms of Metal.

Long Tons..

	1913	1917	1919	1920	1921
British—					
Australia	46,493	39,429	19,183	26,595	10,971
Canada	34,365	48,762	33,506	36,429	23,876
Union of South Africa ...	8,262	8,028	3,521	1,058	90
S.W. Africa Prot.	7,000	1,000	2,450	4,290	7,313
Other British Countries ...	1,500	6,309	4,243	4,137	4,159
Foreign—					
United States	551,594	846,175	541,221	546,674	208,121
Japan	66,835	109,307	77,042	66,582	53,126
Mexico	51,747	50,127	51,432	48,401	14,983
Chile	41,586	100,879	78,300	97,885	74,989
Peru	27,330	44,450	38,600	32,452	32,749
Spain	47,300	44,812	62,256	22,409	30,659
Russia	33,700	13,300			
Germany	25,950	31,750	16,992	15,875	17,009
Belgian Congo	5,324	27,055	22,634	18,657	29,974
Other Foreign Countries ...	45,000	90,000	46,000	45,000	44,000
Total British	98,000	104,000	63,000	73,000	47,000
Total Foreign	896,000	1,358,000	934,000	894,000	506,000
World's Total ...	994,000	1,462,000	997,000	967,000	553,000

World's Production of Lead Ore in Terms of Metal.

Long Tons.

	1913	1917	1919	1920	1921
British Empire—					
United Kingdom	18,130	11,247	10,277	10,961	5,430
Northern Rhodesia (a) ...	291	3,663	12,656	14,602	17,686
South-West Africa Territory ...			4,100	7,200	14,921
Union of South Africa ...	159	117	279	266	171
Canada	24,021	17,275	14,351	15,090	29,973
India	2,600	15,100	32,400	45,700	47,300
Australia	250,788	170,586	70,401	14,360	83,878
Total British Empire	295,989	217,988	144,500	108,200	199,400
Foreign Countries—					
Austria Hungary	20,300		4,423*	3,784*	2,702*
Czechoslovakia	(b)	(b)	(b)	1,200	1,800
Germany	78,000	66,100	48,300	44,000	39,000
Greece	15,679	3,956	300	2,555	5,600
Italy	24,308	20,898	17,095	21,913	14,417
Spain	175,900	140,500	104,511	107,498	98,202
Sweden	1,200	3,100	1,135	1,894	1,000
Algeria	10,100	12,500	4,700	7,300	6,500
Tunis	22,600	18,800	10,100(a)	11,200(a)	17,600
Mexico	67,245	63,094	70,229	81,192	59,540
United States	446,596	581,204	396,155	457,941	361,808
Argentina	500	2,700	3,900	3,400	3,000
Peru	3,864	1,251	1,049	553	400
Japan and Korea (a)	3,709	16,217	5,668*	4,093*	3,082*
Other Countries (estimated) ...	40,000	10,000	20,000	20,000	20,000
Total Foreign Countries	910,001	940,320	688,000	769,000	635,000
World's Total ...	1,206,000	1,158,000	832,000	877,000	834,000

(a) Smelter production. (b) Included with Austria. * Austria only.
*Japan only.

WORLD'S PRODUCTION OF ZINC ORE IN TERMS OF METAL.

Long Tons.

	1913	1917	1919	1920	1921
United Kingdom	5,823	2,735	2,436	1,655	374
Union of South Africa	—	—	—	1,219	455
Canada	3,156	28,864	26,768	40,640	35,232
Australia	216,215	157,582	65,057	10,076	139,460
Total British Empire	225,194	189,181	94,261	53,590	175,521
France	13,000	5,300	5,000	1,200	1,000(a)
Germany	246,300	209,700	134,300	148,000	108,000(a)
Greece	10,745	3,684	831	657	600(a)
Italy	63,886	33,397	33,877	38,486	27,860
Russia	30,900	2,200	—	—	1,100
Spain	39,454	35,621	30,260	27,895	15,567
Sweden	17,737	17,393	17,164	16,335	10,000(a)
Algeria	36,000(a)	18,400	5,800	11,400	6,000
Tunis	1,900	9,600	20,000(a)	3,000(a)	3,400
Mexico	5,539	44,455	11,414	15,399	1,237
United States	373,555	636,928	490,395	522,118	223,000
Indo-China	21,857	19,614	7,500	3,342	5,200
Japan	15,000	70	—	—	—
Other Foreign Countries (estimated)	10,000	5,000	5,000	7,000	6,000
Total Foreign Countries (estimated) ...	886,000	1,041,000	762,000	795,000	409,000
World's Production (estimated) ...	1,111,000	1,231,000	856,000	848,000	584,000

(a) Estimated.

WORLD'S PRODUCTION OF TIN ORE IN TERMS OF METAL.

Long Tons.

	1913	1917	1919	1920	1921
United Kingdom	5,288	3,936	3,272	3,065	679
Nigeria	3,872	5,820	5,718	5,167	5,067
Swaziland (a)	270	321	336	314	287
Union of South Africa	2,251	1,598	1,282	1,429	720
India	303	607	1,236	1,648(c)	1,362
Straits Settlements	7	7	3	1	—
Federated Malay States	50,125	39,832	36,935	34,935	34,490
Unfederated Malay States ...	1,241	3,063	2,303	1,992	1,611
Australia	7,780	4,940	4,331	4,206	2,650
Total British Empire	71,137	60,124	55,416	52,757	46,866
Bolivia	26,327	27,558	28,745	29,067	18,636
China	8,408	11,809	8,742	10,566	11,200
Siam (b)	6,747	9,153	8,542	6,201	7,000
Dutch East Indies (d)	20,541	20,702	19,196	19,879	21,246
Other Foreign Countries (estimated)	500	1,000	500	1,000	1,000
Total Foreign Countries (estimated) ...	62,600	70,700	66,000	66,700	59,000
World's Production (estimated) ...	133,700	130,000	121,000	119,500	106,000

(a) Years ending 31st March of the year stated.
(b) Years ending 31st March of the year following that stated.
(c) Excluding tin contained in 1,223 tons of low-grade ore produced in Burma.
(d) Fiscal years.

WORLD'S PRODUCTION OF BAUXITE.

LONG TONS.

	1913	1917	1919	1920	1921
United Kingdom	6,055	14,724	9,221	11,020	2,269
British Guiana	—	2,037	1,967	22,084	19,694
India	1,184	1,363	1,682	3,932	6,652
Total British Empire	7,239	18,124	12,870	37,036	28,615
Austria	—	160,501(a)	(b)	356	2,596
France	304,323	118,973	160,820	183,693	83,577
Germany	—	10,600	9,200	12,200	—
Italy	6,840	7,664	2,924	12,928	48,311
Jugoslavia	—	—	(b)	(b)	(b)
Spain	—	—	1,751	531	181
United States	210,241	568,690	376,566	521,308	139,550
Total Foreign Countries (estimated) ...	622,000	866,500	561,000	740,000	294,000
World's Production (estimated) ...	629,000	885,000	574,000	777,000	323,000

(a) Dalmatia and Istria.

(b) 27,000 tons were produced in Dalmatia from end of 1918 to 1921.

DISCUSSION.

THE CHAIRMAN said that Sir Richard Redmayne's most interesting address supplied food for thought, not confined to the hour occupied in its delivery, but it would command study in homes and in shops. He had been particularly interested in one of the earlier remarks, the somewhat startling statement that the supply of certain of the base metals would be exhausted long before either coal or iron ceased to be produced. If Professor A. G. Sargent was right when he wrote in 1913 that the supplies of coal in Great Britain could last only for 500 or 600 years, in the United States 1,500 years, in Germany 2,000 years, and in the rest of the world 3,000 years, then the variation that would take place in the consumption of base metals would be as great in this country as in any other country. He thought, however, the author had not estimated the possibilities of the world in the way of discovery. The United States had been the great producer of some of the metals in question, and the discoveries there had only been made in comparatively recent times. In other parts of the world discoveries had only just begun. He doubted, for instance, whether the mineral resources in the Congo had been tapped to anything like the degree that might be possible in the future. The British Empire had never been really properly examined. Science must come to the rescue in that respect. The mining engineer and the expert must wander about with an eye open to the deposits that might be required, and he trusted that discovery upon those lines might be of value in the future. There was another type of discovery to which the author repeatedly referred, and he illustrated it by several remarkable examples, perhaps the most striking of which related to electrolytic zinc, a commercial process which was largely expanded during the War. He alluded also to other possibilities that might, at present, be only in the experimental stage, but which might be brought to commercial uses in the not very distant future. In the case of every one of the metals of which he had spoken he referred to the different processes and possibilities that existed. For instance, he had given some very striking examples of the numerous processes that might be used for extracting the copper in a cheap manner, and by a method that was perhaps more satisfactory in saving some of the loss that would otherwise result. There was a great field in the future for such methods. In view of the statement the author had made that other countries were the chief exporting countries for different metals, while Great Britain, in at least two instances, was the chief user, it became more and more necessary that this country should try within its own Dominions and by means of its own kith and kin, to exploit the sources from which the metals were derived and endeavour to bind the Empire together by the use of those refractory metals.

SIR THOMAS H. HOLLAND, K.C.S.I., K.C.I.E., F.R.S., Rector, Imperial College of Science and Technology, said he had been very severely criticised by the author for having impressed upon him the duty of bringing the subject before the attention of the Society, but he was perfectly sure that those present would agree, after hearing the paper, that if he had lost a

friend in the author he had found a very much larger number of grateful friends among the members. His reason for recommending an authoritative general survey of the non-ferrous base metals was due to the very peculiar position they occupied and the bearing they had on the progress of civilisation. Man's first essay in the art of metallurgy was in connexion with non-ferrous base metals, when some pre-historic Minister of Munitions discovered that instruments of warfare more efficient in character and greater in variety than stone could be made by copper hardened by tin to form the alloy bronze. The subsequent use of iron might have replaced bronze to some extent, but at the same time it introduced new uses in other directions, not accessory and ornamental, but in ways which were now absolutely essential to civilisation. In that way they came up against the question of raw material supply, for the base metals were among those elements that were comparatively rare constituents of the earth's crust. The Chairman had mentioned the possibility that the author might be wrong in assuming that base metals would run out at an early date, but he asked the audience to consider the following figures. Zirconium was generally regarded as a rare element, but in the earth's crust there were fourteen times as much zirconium as copper. Only about 1,000 tons of vanadium were produced a year, but there were ten times as much vanadium in the earth's crust as copper, of which 1,000,000 tons a year were produced. Nickel, which was also a relatively rare metal, occurred in the earth's crust to an amount nine times as great as that of copper, but while 30,000 tons of nickel were produced per annum, a million tons of copper were made. Zinc and lead were even more scarce than copper; they did not come into a third place of decimals in an average percentage analysis of the earth's crust. So that, if the world went on producing metals which were relatively rare, such as copper, zinc and lead, in such enormous quantities, the stage would soon be reached when civilisation would suffer from a base-metal famine. He was rather inclined, therefore to support the very cautious statement the author had made, namely, that the supply of certain base metals would be exhausted long before either coal or iron ceased to be produced. That was a comparative statement. What applied in the way of scientific progress and further discovery of new occurrences of the base metals would apply to coal and iron. The question, therefore, had to be faced of whether there existed in the earth's crust a sufficient concentration of the base metals to meet the enormous demand being made upon them. When it was also realised that the United Kingdom alone, without Ireland, was consuming a larger quantity of the base metals than was being produced in the whole of the Empire, in all cases except tin, it was apparent that this country would have to be very careful in the future when it went to war that it chose as its allies those that could provide it with the necessary materials. The author had drawn attention to the waste that occurred in mining and in ore dressing and smelting. Another important feature was the extraordinarily limited way in which those metals were concentrated in the earth's crust. It was impossible to use the average rock that contained copper, zinc, lead or tin; it was necessary to rely only on those local concentrations that had been brought about by long processes of nature, and they only could be turned to commercial account. In the case of a deposit of iron ore, it was only necessary to get a local concentration of five or six times the average iron content of the earth's crust in order to get a workable ore; but in the case of copper, it was necessary to get a concentration of something like 2,000 or 3,000 times, and the same remark applied to zinc and lead. That was one reason why the workable deposits of those particular base metals would be exhausted before such a metal as iron. He had taken as a rough idea of the relation between the total quantity of those ores that were in the earth's crust within an accessible distance and the quantity of ore that was likely to be worked, and the figures indicated that not more than about one-millionth of the copper, zinc and lead would be obtained; about one two-hundred-thousandth of the iron and a much larger fraction of the aluminium The author had called attention to the fact that progress in metallurgy would overcome some of the existing difficulties, and the Chairman had accentuated that point. But it must also be remembered that every step in the increased cost of labour had an opposite effect. A Trades' Union Conference could undo in a morning sitting the result of a life-time of metallurgical research, and could thus shorten the life of civilisation by several generations. In South Africa, the average cost of working a ton of gold ore before the War was just under 18s.; in 1920 it was over 25s. That meant that millions of gold ore that were previously regarded as reserves must be written off as absolutely worthless; and in the same way elsewhere in the world costs had gone up, in metalliferous mining especially. Due to those causes some tin, lead, zinc and copper mines had gone out of action for ever, and what was far more important, the radius of prospecting for new mines had consequently been shortened. Areas that would have been worth looking into previously were now no longer regarded locally as pay ore, and they consequently would not be searched for. There was, in his opinion, probably far more room in base metal mining and metallurgy than in any other mineral industry for obtaining good results, not only in the way of metallurgical

progress but in labour economy as well. Aluminium had been referred to by the author as a metal that might possibly take the place of tin, and, in some respects, the other non-ferrous base metals, zinc and copper, but that assumption could only be agreed to with a certain amount of qualification. It was necessary to remember that although aluminium was impressive on account of the fact that it constituted 8 per cent. of the earth's crust, only a very small fraction of that was in a form that was available for metallurgical treatment. When one went a step further and brought into action the pure clays that contained large percentages of aluminium, it was necessary to take a very big jump—in fact, a double jump. One was that they passed from an oxide as the raw material to a silicate, and a technical difficulty there had to be overcome. The other was that a raw material had to be dealt with which could never, under theoretically perfect conditions, contain more than 18 per cent. of the metal. Going a step further, and taking felspar, they had to deal not only with a silicate, but with a silicate that contained a less percentage of aluminium than clay did. So far as he could see, therefore, civilisation would suffer a very severe base-metal famine before aluminium would be extracted from the purest clays. Before that stage was reached science and art would have progressed and aluminium would have found other uses. On the whole, he agreed with the author in regarding the relative exhaustion of base metals as a condition that must be faced in the relatively near future. He would not make a guess as to how far off it was, but he thought he was safe in saying that, while it would not affect this generation, in a generation or two hence people might find it a very serious matter to find substitutes for the present metals. He was satisfied that he had been instrumental in utilising the author's position as chief watchman on the conning tower of imperial mineral intelligence, for he had given the Society an excellent perspective survey of that very important question.

Professor Thomas Turner, M.Sc., A.R.S.M., F.I.C., said everyone realised how important it was from an Empire point of view that full information should be available in regard to its resources. It was desirable to know not only what things were required but where they were to be found and in what quantity they existed. From that point of view the work of the Imperial Mineral Resources Bureau was of extreme importance. Sir Thomas Holland, who had practically given another interesting paper, had raised some questions, metallurgical and otherwise, which might be discussed at considerable length. He thought the metals in question were miscalled base metals, because aluminium could not be considered as a base metal, and he saw nothing that was base in the properties of copper when it was used for the conduction of electricity. But it was perfectly clear that the question of the supply of base metals in the future was of extreme importance. In a reasonable time aluminium might be used, but he agreed with Sir Thomas Holland that it would be a difficult problem in view of the fuel that had to be provided and the cost of production, and that the important question was to economise the supply of base metals they now possessed. The author had pointed out the direction in which development was most likely to take place. During the generations in which the metals had been extracted, obviously the surface had been skimmed of its richer deposits. Here and there some unexpected rich deposits would again be found. The best of the deposits of tin, lead and gold had been very largely picked over by the old Egyptians, who were very good miners, the Phœnicians and the Greeks, not to mention the British people. Large quantities of poor ores now had to be dealt with, and the quantity of ore supplies that was visible was increasing rather than diminishing. Hence, in the case of copper, they were now dealing not with 25 or 20 per cent. ores, as was the case at one time, or with 12 per cent. ores as was the case when he was a student, or even 4 per cent. ores, but they now had to consider the possibility in the future of dealing with ores of only 1, 1½ and 2 per cent. If it was possible to extend the field in that direction, then they might be able to look forward to a larger supply of copper. It was perfectly clear that ores of that kind could not be treated by smelting processes; the cost of smelting the infusible material and making slags would render it quite prohibitory. Fortunately, the great invention of flotation had given a wonderful fillip in that direction, and the use of hydro-metallurgical processes made it possible to treat ores of very low grade. The development of the electrolytic zinc deposition process had been very remarkable during the past ten years. Less than ten years ago he was interested in a number of experiments in connexion with the Tasmanian Government, and they succeeded in showing that the zinc could be dissolved from the ore and precipitated on a commercial scale at a paying price in this country. Then came the trouble of the War and the subject was developed under other auspices on an enormously large scale; and in reference to zinc, where water-power was cheap and electricity was available, the production of zinc from the world's point of view did not rest with the smelting process, but with hydro-extraction and electrolytic deposition.

The Right Hon. Lord Morris, P.C., K.C.M.G., K.C., LL.D., said he was sure everyone present would admit that they were the gainers by the severance of the lifelong friend-

ship between the lecturer and Sir Thomas Holland, and it would be some little consolation for those gentlemen to know that the world in general had benefited by that severance. He had had the advantage during the last five years, as a member of the Imperial Bureau of Mineral Resources, representing one of the Dominions, of co-operating with the lecturer and Professor Turner. He could not claim to speak from a scientific standpoint, and he, therefore, could not add anything to what had been said by the previous speakers. He trusted, however, that the Royal Society of Arts would not allow the proceedings connected with the paper to rest with its reading and discussion, but that the Government or departments which were largely responsible for the results quoted in the paper would have those facts brought home to them. Up to the present time, the discovery of lead, copper and other of the mineral resources of the Empire had been left largely to accident and chance, and very often the discoverers feared that they would not be given any protection if they made known the value of their discoveries, and they ran the risk of having them stolen by somebody else. The author had pointed out that in the last year before the War, the British Empire produced something like six per cent. of the world's copper. The Empire, with a population of something like one-third of the whole world, should have been producing something like 33 per cent. of the world's production. Six per cent. was not enough, and the Empire ought not to be satisfied with the result, until it was known with absolute certainty that there was no copper in the Empire worth prospecting, developing and working. For many years the Cape Copper Company of Newfoundland worked successfully in exporting to this country tens of thousands of tons of copper, and the Company paid very large dividends. All over Newfoundland there were indications of copper, but, unfortunately, that Dominion was not on the visiting lists of capitalists and prospectors. During the present year, Newfoundland had contracted with Germany to supply over a million tons of iron ore, and at the time the French entered the Ruhr district it had already supplied something like 800,000 tons of that amount. There was no reason, that he knew of, why every ton of that iron ore should not have been sent to this country, and been utilised to lessen the amount of unemployment that existed. It was from that practical standpoint that he would like the Society to bring the paper to the notice of the Government and others whose duty it was to look into such matters, because he was inclined to believe that if one-tenth or one-twentieth or one-hundredth part of the money that was spent at the present time in doles was spent in prospecting, exploring and developing the minerals of the British Empire, very little unemployment would exist in the future. He was a member of the Imperial Bureau of Mineral Resources because he believed that in the development of the minerals of the Empire lay the most important means of saving the industrial position of this country. If the minerals of the Empire were being developed as they ought to be, and the raw material brought to this country there would not be, as there were at the present time, 1,500,000 people out of work. The unemployed did not consist of miners, because there were now more men working underground than before the War, and as many men were working at agriculture as before the War. The manufacturing classes, who manufactured for the Overseas trade before the War, were idle. Everything that could be done to bring raw materials, particularly mineral resources, into this country, would tend to employ labour, and in that way the objects for which the Royal Society of Arts were founded would be carried out.

MR. THOMAS CROOK, Chief of the Intelligence and Publications Section, Imperial Mineral Resources Bureau, said the paper covered a large field, and the author had touched briefly on many topics concerning the base metals that were well worthy of discussion. The statistics given in the Appendix showed the great magnitude of the base metal production during and just previous to the War. The production had increased gradually with industrial development during the 19th century and after, and they were compelled to infer that the uses of the base metals, especially copper, lead, zinc and tin, played a vital part in that development. Whether those metals were really necessary for the maintenance and development of industries, or merely convenient and replaceable, the world might soon have an opportunity of testing; for it looked as if the earth's store of those metals would be exhausted at no distant date. It was not surprising to find, on looking into the figures showing consumption, that Europe and North America, the joint population of which was well below a third of the world's total, consumed not less than 95 per cent. of the world's output of base metals, and even the remaining 5 per cent. was accounted for mostly by the comparatively small industrial communities in other parts of the world. It was not extravagant to assume that, in the next half century, the combined requirements of Europe and North America would reach two million tons each of copper, lead, and zinc annually. It was reasonable to anticipate industrial developments in China and other backward countries, and if these developments were to attain the same magnitude as those of Europe and North America the world would require five or six million tons annually of each of the metals copper, zinc and lead. He would be something of a pessimist who doubted that possibility of the world's industrial

development; but he would be a very rosy optimist indeed who believed that five or six million tons each of copper, lead and zinc could be produced annually from the present date for more than ten or twenty years. The author had been content to say that the deposits of certain of the base metal ores would be exhausted long before those of coal and iron ore; but it seemed to him that they might venture to be more definite and safely take the view that another half century or so would see industrial civilisation nearing the end of its supply of copper, lead and zinc. The world's coal reserves were estimated to be sufficient to last at least 1,000 years at the present rate of consumption, while the iron ore reserves would last probably not less than 500 years. The base metal reserves could not be estimated so definitely owing to the irregularity and uncertain extent of their deposits compared with those of coal and iron ore. They knew, however, that there was not altogether more than about 0.02 per cent. of copper, lead and zinc in the average igneous rock.* If they assumed that the ratio of the base metal reserves of the earth to the iron reserves was equal to that of the percentage of the base metals to the percentage of iron in the average igneous rock, and allowed 75,000 million tons of metallic iron for the iron reserves, they would have a total reserve of 300 million tons of copper, lead and zinc. Of that amount probably not less than 120 million tons had been extracted, leaving 180 million tons, which at a rate of consumption of 3½ million tons a year would not last more than about 50 years. The order of abundance of those metals in the earth's crust was copper, zinc and lead, and on that account they might perhaps infer that lead would give out at a fairly early date, while zinc would hold out longer and copper longer still. It could not, of course, be claimed that those figures were accurate, but they might be near the truth. One could perhaps show good reasons why the base metals should be more abundant than was indicated by that estimate; but it would be interesting to know whether there were any mining geologists or engineers who would claim that that estimate was far below the mark. The problem was well worth discussing by those who had a wide knowledge of the world's developed reserves, and who might also have views on potential reserves, with regard to the base metals. The author had pointed out the moral to be drawn from those considerations. Metallurgy had made remarkable progress in recent years in the direction of more effective recovery of metals from ores, but there was still a great deal of avoidable waste going on, and it was clearly a matter of international importance that that waste should be reduced to the utmost extent possible. While that was being done, however, it really looked as if industrial civilisation should begin to consider how it would adapt itself to the circumstances that would arise when copper, lead, zinc and tin were no longer available for use. What would take the place of lead and zinc, especially lead, supplies of which were likely to give out at a comparatively early date? The substitution of copper presented less difficulty, for its place could probably be taken to a large extent by aluminium. Aluminium was more abundant than iron in the accessible rocks of the earth, and when bauxite was exhausted there was an ample supply of other minerals from which the industries of the future would be able to draw any supplies that it might be necessary and economically feasible to produce. That was the hopeful feature of the prospect. It made one less hopeful to think that man before metals was a comparatively feeble creature. When the time came for him to carry on without the aid of the base metals, the extreme usefulness of which he had amply proved, he might reasonably fear that he would be handicapped in his efforts to maintain intensive production of the means of subsistence.

THE HON. SIR JOHN A. COCKBURN, K.C.M.G., thought the point of value the general public would derive from the paper and the discussion, was the enormous debt the world owed to the sciences of electricity and chemistry in enabling a huge quantity of ore to be made highly profitable. As one who had been occupied all his life with education, he had come to the conclusion that no amount of technical education would succeed without safeguarding industries. Since England, with its proverbial ingenuity, had given the go-by to gold, its precious metals were the metals necessary for industry, copper, lead, zinc and tin Copper was the basal metal for the crafts. He thought the terms used in connexion with the industry should be revised. "Base," he thought, meant a sort of gradation in value. He thought the word "basal" should be substituted because such metals were the foundation of our industries and of our welfare. Lord Morris had spoken on his particular pet, Newfoundland. Personally he also had a particular pet, a land which had not yet been discovered, but some day would be—the vast interior of Australia, which was at present a *terra incognita*, but every square mile of which was rich with mineral products, and was yielding at present some of the most valuable materials of high-speed steel and other essential products. The paper was of the greatest value, particularly the Appendix, which he proposed to send out to Australia, where he was sure it would be a sort of guide-book for the instruction of those connected with the fundamental metal trades.

SIR CHARLES H. BEDFORD, LL.D., D.Sc., in proposing a vote of thanks to the author,

said that one of the most significant points that occurred to him in connexion with Sir Richard Redmayne's extremely valuable paper, was the relatively small extent to which the British Empire contributed to the world's production of the basic metals. It was on a par with its contribution to the world's production of mineral oil, which was only about 3 per cent. That pointed to the necessity of a systematic survey and exploitation of the Empire's resources, and a timely stock-taking against that time with which they had been threatened in the future. The Spanish-speaking countries in South America (in addition to Mexico and Brazil) were largely productive of such metals, and that was another point which should be borne in mind, having regard to the very slow development within the Empire. A great deal of loose talk was heard about the unlimited potentialities of the Empire, but when the small progress that had actually been made in developing those resources was borne in mind, it must be admitted that it was pitifully slow. After the British Empire, one of the finest fields of development was South America, into which British enterprise had already, of course, largely entered. The drawing together of the Spanish-speaking countries with the British Empire was a matter of very great importance, and one which he was glad to say was now beginning to receive consideration.

Mr. Byron Brenan, C.M.G., seconded the motion, which was carried unanimously.

Sir Richard Redmayne, in reply, after expressing his thanks for the extremely kind manner in which the resolution had been moved, seconded and passed, said the discussion seemed to resolve itself into two heads, one the date of exhaustion of the several base metals, and the other the meaning of the term "base metals." Everybody agreed that at some time the base metals would be exhausted, and he thought Sir Thomas Holland was more or less in agreement with himself that they would be exhausted in all probability before iron and coal. Mr. Crook took that as his text, and rubbed it in by giving the actual dates. Civilisation as they now knew it was intensely wrapped up in the base metals, and unless something was discovered to take their place the world would be in a difficult position, when their exhaustion was accomplished. Perhaps relief might be found in the wider use of aluminium. With reference to the meaning of the words "base metals," it was simply a term differentiating those metals from gold, silver, platinum and the rare metals. In conclusion, the privilege was accorded to him of proposing a hearty vote of thanks to the Chairman, who had so nobly stepped into the breach occasioned by Lord Emmott having to visit Belgium and thus being unable to preside over the meeting.

The proceedings then terminated.

INDUSTRIAL RESEARCH IN THE UNITED STATES.

The remarkable extension which research work has undergone in the United States in recent years, and its importance for the future of American industry and commerce, are referred to briefly in the Report on the Economic Financial and Industrial Conditions of the United States of America in 1922, by the Commercial Counsellor to the British Embassy at Washington.

The attention paid by the Federal Government to this matter is no new development, and the excellence and wide scope of the work done by the Bureau of Standards under the U.S. Department of Commerce, as well as by the Bureau of Mines and other branches of the Department of the Interior, are well known, but what is perhaps not so generally realised in other countries is the close contact they maintain with American manufacturers and producers, and the immense amount of assistance they give to private industrial concerns in the solution of their technological problems. They have established, moreover, an excellent liaison not only with universities and other educational institutions but with individual students in colleges and institutes of technology. The staff of the Bureau of Standards in 1921 consisted of 342 statutory employees in addition to 508 temporary employees engaged in research and investigations authorised by Congress. The appropriations assigned to the Bureau amounted last year to $1,729,000, but in the present year it is proposed to petition Congress for a considerably increased vote.

In 1916 a National Research Council was founded under the Congressional Charter of the National Academy of Sciences, for the purpose of prosecuting and encouraging research in industry. The work of the Council is divided into two main groups, one of which comprises seven divisions of science and technology, each assisted by advisory Boards and Committees. As an example, at the time of writing the report there were Committees on such subjects as the fatigue phenomena of metals, heat treatment of carbon steel, high-speed tool steels, hardness testing of metals, pulverization, welding, etc. The Division of Research Extension carries on widely diversified activities. In 1920 it helped to found an "Alloys Research Association," assisted the Tanners' Council in the establishment of a "School of Tanning," and initiated investigations in connection with the tobacco plant, macaroni, glass, etc. The Textiles Division made an effort to persuade the industries concerned to undertake the examination of various technological problems. As in the case of the Bureau of Standards, the Council is frequently called upon to advise and assist manufacturers to instal new laboratories or otherwise expand their research organisations. The Council is supported by funds

derived from other than Government sources. In 1920 the Carnegie Corporation gave $170,000 for current expenses while the Rockefeller Foundation, the Commonwealth Fund and other similar institutions contributed largely to its upkeep and expansion. To support the investigation on the fatigue phenomena of metals, the General Electric Company in 1920 gave $30,000, while the Du Pont de Nemours and the General Motors Corporation provided $5,000 and $2,500 respectively for the special use of the Council's research information service.

The most notable feature of the industrial research movement, however, is the great amount of investigation work which is being carried on by various manufacturing firms and trade associations quite independently of official support.

In a very interesting publication recently issued by the National Research Council particulars are given of the work done and the staff employed in the private laboratories of some 526 firms and organisations throughout the country, from which some idea can be gained of the general activity in this direction which cannot fail to bring about much improvement in American industrial efficiency.

POTASH SALTS IN POLAND.

The Polish fields of potash salt are situated near the mines of cooking salt in the Carpathian region of Galician Poland. The fields already exploited are in the districts of Kalusz, Stebnik, and Morszyn. Polish engineers maintain that there is potash in many other parts of Poland. Kalusz has the most extensive and richest deposits, with a high percentage of pure potash: these occur as kainite and sylvine, with a secondary layer of carnallite.

Potash mining in Poland dates back to 1862; but as the mines were the property of the Austrian Government and subject to governmental apathy, the industry did not develop to any appreciable extent until 1900, when State restrictions became less severe. From 1900 to 1912, inclusive, the total production of the Kalusz fields amounted to 170,000 metric tons, or an average of slightly over 13,000 tons a year. In 1913—a period of transition from Government to private ownership—the production fell to 2,344 tons. There are no figures for the war period, when the industry was practically idle. Work recommenced in 1919, and in 1920 the production reached 6,789 metric tons. During the entire 50 years of State ownership the Austrian Government made only five new borings.

The production of potash in Poland up to the present time has been only a fraction of the German output, which in pre-war years averaged about 1,600,000 metric tons annually; but extensive prospecting is being conducted. According to information furnished by the United States Trade Commissioner at Warsaw, five new deposits have been discovered at Kalusz within a comparatively small area tested, and several new companies have been organised.

Polish chemists maintain that the Kalusz salts are equal to the Alsatian salts. They also declare that these natural salts are superior in quality to those chemically concentrated. Kalusz kainite is said to contain 10 per cent. oxide of potash, and Kalusz sylvine from 20 to 30 per cent. of potash. Stebnik potash salts, according to Polish chemists, contain 25 per cent. sulphate of potash.

Nearly all of Poland's pre-war potash production was used in Galicia and Bukowina. About one-fifth, in the form of potash fertiliser, was exported to Moravia, Austria, and Dalmatia. Practically the entire production of chlorites went to the Vienna ammunition factories.

EFFECTS OF ELECTRIC SHOCK ON THE HUMAN SYSTEM.

The danger to life in an electric shock consists in the fact that it affects the muscles of the heart, stopping the heart's action.

The current which, when passed through the heart muscles, will give a fatal shock to a person in normal health, is about 0.1 amp.; the voltage necessary to cause this current to flow depends, naturally, on the resistance—this mainly on conditions of contact. Even 110 volts has been known to give a fatal shock when the surfaces of contact have been large and moist. Contact with two hands is less dangerous than that, say, between the left hand and the right foot, as in the former case the heart is not in the direct flow of the current. Persons with heart ailments are likewise more susceptible to fatal shock than healthy persons. Horses, incidentally, are more liable to fatal shock than human beings.

The effects of alternating current at the usual commercial frequencies (40/50) are more severe than those of direct current, but at very high frequencies (say 4,000-8,000) the nerves cease to re-act, and electricity at such frequencies is, therefore, not dangerous to life, which fact is taken advantage of in medical apparatus.

Serious burns are more frequently a consequence of direct current than of alternating current shock.

Experiments with the electric chair in America have proved that if a person is expecting the shock a much more severe one can be resisted.

The treatment for electric shock cases is, as is well known, to endeavour to restore the suspended action of the heart by artificial respiration. It is noteworthy that the effects of electric shocks, if not immediately fatal, seldom last longer than a few hours, apart from incidental burns.

NOTES ON BOOKS.

THE A.B.C. OF ENGLISH SALT-GLAZE STONEWARE, FROM DWIGHT TO DOULTON. By J. F. Blacker. London: Stanley Paul and Co., 15*s.* net.

Stoneware is of special interest as being a true porcelain; its body, or mass, consisting of a refractory clay, incorporated more or less intimately with a fluxing material, but not in sufficient quantity to render the mixture "tender," or too fusible in the kiln.

Thus stoneware is especially suited for salt glazing which is done by charging the atmosphere in the kiln with vapourised sodium chloride, under which circumstances the intensely heated articles undergo a kind of superficial deliquescence attracting soda; and being hardened on the surface, but not glazed in the older and usual senses of the term.

Although it is *possible* to make salt glazed stoneware which is quite white, the pottery, ordinarily known as salt glazed stoneware, is reddish brown on the surface, from the presence of ferric oxide, and olive brown on its fracture from the presence of ferrous oxide; typical examples of such stoneware being the Bellarmines or black jacks depicted on p. 13 of this work. These were manufactured by Dwight at Fulham about 1675, and we read that Dr. Plot, in writing of such ware, referred to Dwight as having discovered the mystery of the Hessian wares, suited for retaining the salts and spirits of the chemist.

The most notable characteristic of good stoneware is here recognised as its durability, but Mr. Blacker tells us of, and illustrates, wonderful modellings—Dwight's masterpiece, the bust of Prince Rupert, being reproduced as the frontispiece of the book—and hundreds of notable works in stoneware are depicted. Although at first sight stoneware may appear ill suited for effects in colour, we are told how, by layering with coloured slips, incising, scraping-out and more especially by enamelling, on the salt-glaze surface, quite surprising colour effects are obtained, to say nothing of the one-firing colour method to be touched on later.

At one time, the quality of the English stoneware appears to have retrograded, and the output of the Mortlake pottery—we assume about 1813—is accorded the very faint praise of "fair quality, but of no artistic value." The author's "period of decadence" (p. 21), is not precisely dated, but by the context it may be regarded as closely following 1760.

In touching upon the revival of stoneware in the early part of the nineteenth century, Mr. Blacker is strangely silent regarding the fruitful labours of Joseph Bourne, who devoted a long lifetime to the detailed improvement of the mass or body, first at Codnor Park, and afterwards at Denby (Derbyshire). Mr. Bourne was awarded a medal by the Jury of the 1851 Exhibition, on the sole ground of the proved durability or resistance of the ware to solvent action—" in a manner which had been found difficult of attainment." (Reports of the Juries, 1851, p. 541.) Although we find in the work under notice two representations of decorative Denby ware, we find no mention of the Denby pottery (afterwards Joseph Bourne and Son), or of the somewhat palatial establishment of Bourne and Pinder at Cobridge; this latter, however, has passed into other hands, but we believe the Denby pottery retains its old lead in regard to insulators, battery cells and such like specially resistant wares.

Mr. Blacker's concluding chapter vividly describes the operation of salting the stoneware kiln at the Lambeth works of Messrs. Doulton & Co., Ltd., and in special reference to the single firing method of this firm for colour effects, as explained on pp. 113-114, contrasted with the older enamelling process described on pp. 21 and 102.

LUBRICATION AND LUBRICANTS. By J. H. HYDE. No. 56 in Pitman's Series of Technical Primers. London: Sir Isaac Pitman and Sons, Ltd. 1922. 2*s.* 6*d.* net.

Concise, lucidly written, and accurate, this primer deals first with the scientific principles which underlie friction and its minimisation by lubricants, whether fluid or solid: indeed the chapter on Solid Lubricants (pp. 61-66), the chief of which are graphite, talc in its various forms, and flowers of sulphur, is of quite special interest. On page 6, under the heading "Variation of Friction with Nature of Surfaces," we have mention of an interesting aspect of friction in the case of cast iron, which we may suggest is well exemplified by the functioning of the Bisschop gas engine manufactured on a somewhat large scale about 1881, and in the printed instructions for running we read: "Oil in the cylinder. This is the most important point to be guarded against." Probably but few examples of this engine have survived that usual fate of engines, the scrap heap; but we believe there is one in the Science Museum; a matter for satisfaction, as many lessons are to be learned from this somewhat early and very noteworthy form.

Next we have chemical and physical testing of lubricants, including considerations as to suitability for special uses, this section being very thorough and well illustrated, and at the end of the book there are details as to a variety of special modern devices for the application of lubricants in difficult cases, as to turbine gears, aero-engines, automobiles, and to some various special forms of axle-bearings and steering gear.

Everyone who has to do with machinery should be able to learn something of value to himself from this well arranged and up-to-date booklet.

SPECIAL STEELS. By Thos. H. Burnham. Double Volume in Pitman's series of Technical Primers. London: Sir Isaac Pitman and Sons, Ltd. 1923. 5s. nett.

This may be regarded as in sequence with Pitman's Primer on the Metallurgy of Iron and Steel which was noticed on page 704 of the *Journal* of August 25th last.

Accepting the definition of "Special Steels" or "Alloy Steels" as given on page 2 ("steels which owe their properties chiefly to the presence of an alloying element other than carbon,") we may perhaps consider that special steels were a leading factor in determining the result of the great war; as the choice available by the Allies allowed advantage to be taken of many of those mechanical properties which can be obtained with alloy steels suitably treated, as hardness, toughness with high elasticity in axles or crankshafts, and perhaps most important of all a sturdy resistance to the tendency of alternating stresses or quick-following shocks to produce fatigue and ultimate fracture. As regards the present aspect, and in special application to motor car work, Sir Robert Hadfield, in a foreword to the present volume, with the British habit of looking rather to the future by the light of the past than to the past as such, emphasises the urgency of economy in the case of iron, in order that wastage by corrosion or rusting may be minimised: one method of economy being to use those modern alloy steels which will do tenfold service compared with the older outputs. Moreover, there is constant progress in the production and use of steels having but little tendency to rust.

The account of such special steels or alloy steels as have come into use since the critical period in the steel industry is detailed and thorough. Take, for instance, Chapter IV. dealing with chromium steel: it has been already mentioned (p. 3), that Faraday, as far back as 1822, made a chromium steel; but we had to wait ninety years for a chromium steel capable of taking a cutting edge. The manufacture, structure, treatment, and uses of chromium steels having been considered, we have a long account of the rustless chromium steels which are usually made in an electric furnace, and contain from 11 to 15 per cent. of chromium and usually something under one-half per cent. of carbon. Traces of silicon manganese sulphur, nickel and phosphorus may be present. Heat treatments and mechanical factors are tabulated and plotted, and on p. 75 numerous important applications from razors to ship construction are indicated; but perhaps quite as important is the rustless soft iron (p. 77) which is really the above-mentioned rustless steel with the carbon reduced to a minimum. As the production of such rustless soft iron is cheapened, it may not only revolutionise the small ware industry (as kitchen ware, bicycles and motor car parts), but also large structural work.

As regards the economic aspect, it must be remembered that the scrap of such metal can be very readily remelted in an electric furnace of the kind depicted on page 30 (the 6-ton Heroult furnace which, during wartime, was used to melt some 120,000 tons of unserviceable scrap, as turnings), and the abundance of minerals containing chromium and iron lends hope for the cheap direct production of rustless iron.

In summary we have here a concise, well illustrated, clearly expressed, and reliable account of special steels as used at the present time, and which are largely due to the labours of Sir Robert Hadfield.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, JUNE 25.. British Architects, Royal Institute of, 9, Conduit Street, W., 8 p.m. Mr. G. Scott, "Tradition and Originality in Italian Renaissance Architecture."

TUESDAY, JUNE 26.. Gas Engineers, Institution of, City Hall, Belfast, 10.30 a.m. Annual General Meeting. Presidential Address and Discussions.

Anthropological Institute, 50, Great Russell Street, W.C., 8.15 p.m. Mr. S. H. Warren, "The Paleolithic Succession of Stoke Newington."

Sociological Society, at the Royal Society, Burlington House, Piccadilly, W., 8.15 p.m. Dr. E. Jenks, "The Function of Law in Society."

Colonial Institute, Hotel Victoria, Northumberland Avenue, W.C., 4 p.m.

Royal Dublin Society, Leinster House, Dublin, 4.15 p.m. 1. Mr. H. G. Beckor, "Studies in Common Laboratory Operations—1, Evaporation." 2. Messrs. H. G. Beckor and W. E. Abbott, "A Rapid Gasometric Method of Estimating Dissolved Oxygen, and Nitrogen in Water." 3. Mr. W. R. G. Atkins, "The Hydrogen ion concentration of the soil and of natural waters in relation to the distribution of snails."

WEDNESDAY, JUNE 27.. University of London, University College, Gower Street, W.C., 6.15 p.m. Sir Josiah Stamp, "Economical and Statistical Aspects of a Capital Levy." (Lecture VI.)

Gas Engineers, Institution of, City Hall, Belfast, 10.30 a.m. Annual Meeting continued. (1) Mr. S. Lacey, "The Flow of Gas in Pipes." (2) Report on "The Gasification of Coke in Steam, with Special Reference to Nitrogen and Sulphur."

In the Physics Lecture Theatre, Queen's University, Belfast, 8 p.m. Prof. W. B. Morton, "The Flow of Gas."

THURSDAY, JUNE 28.. Gas Engineers, Institution of, City Hall, Belfast, 10.30 a.m. (1) Mr. A. M. I. Cleland, "Distribution in Belfast." (2) Mr. G. Braidwood, "Ammonia Yields from Vertical Retorts." (3) Report of Refractory Materials.

Antiquaries, Society of, Burlington House, Piccadilly, W., 8.30 p.m.

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICE.

ANNUAL GENERAL MEETING.

WEDNESDAY, JUNE 27TH, 1923. LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, in the Chair. The One-hundred-and-sixty-ninth Annual General Meeting of the Society was held for the purpose of receiving the Council's Report, and the Financial Statement for 1922, and also for the Election of Officers and new Fellows.

A full report of the Meeting will be published in the next issue of the *Journal.*

PROCEEDINGS OF THE SOCIETY.

NINETEENTH ORDINARY MEETING

WEDNESDAY, APRIL 25TH, 1923.

CONFERENCE ON THE MILK QUESTION.

THE RT. HON. F. D. ACLAND, M.P., in the Chair.

THE CHAIRMAN said that not very much progress would be made with regard to the consumption of more milk, and better milk, (and, he thought, also cheaper milk) unless and until there was something in the nature of a combined campaign by all those interested in the matter. At present the farmers were waiting to put their house—or should he say their cowsheds ?—in order until somebody else made a move and showed them it was worth doing. The United Dairies, it was reported, could quite well reduce the price of milk by 1d. and yet make reasonable profits ; but they also seemed to be waiting. Other people seemed to be waiting too. Unless there was something very definite in the way of a united campaign by all people engaged in milk production—by Medical officers of Health, by doctors, by the Government and by the Railway Companies—not very much progress would be made. He believed it would be a thoroughly good investment on behalf of the State if they were to put £100,000 or £200,000 into a great campaign for popularising and extending the consumption of the best sort of milk. He supposed it would not be done, but it was that sort of campaign, which would really get hold of the public imagination, that seemed to be necessary. He thought the state of the country at the present time in regard to the question could be summed up in the saying that, "A little learning is a dangerous thing." He went to an office where the ladies on the staff were very anxious to do the right thing, and so they drank bottled milk instead of drinking it out of a can. He had seen the process of bottling milk the other day. The milkman had poured the milk out of his can in the street into a bottle, then he had taken a capsule out of his waistcoat pocket, had given it a lick, had stuck it on the bottle, and then had handed it at the door. That was bottled milk !

The papers read were :—

ARGUMENTS FOR MAINTAINING AN OPEN MARKET FOR FRESH MILK.

By

PROFESSOR R. STENHOUSE WILLIAMS, M.B., B.Sc., L.R.C.P. and S.E., D.P.H.

If one is to attempt to support the view that the market for raw milk should be kept open, it is very important that one should be in a position to demonstrate that it is possible to provide the public with a raw milk of sufficient cleanliness. I have, therefore, set out the figures showing the results which have been obtained from the examination of Grade A milk from tuberculin tested cows as it is being delivered to the consumer in Reading. It will be within the knowledge of most of you that there are, at the present time, two grades of milk which are derived from tuberculin tested cows—Certified milk and Grade A (tuberculin tested) milk. The essential difference between these two types is that certified milk must be bottled at the farm, whereas Grade A milk may be sent in sealed churns from the farm to the dealer's premises where it is bottled. As a fact, so far as our knowledge goes at present, we do not find that there need be any material addition to the numbers of bacteria in the milk during the process of bottling. This is, of course,

a most helpful observation if it can be confirmed by a greater number of experiments than we have yet been able to carry out. From the consumer's standpoint there are three things to be considered about these two types of milk :—First, the fact that Grade A milk must be handled rather more than certified ; second, that the bacteriological standard required is not so high as that for certified—200,000 colonies in 1 c.c. as compared with 30,000 ; third, that its price is, as a rule, less than that of certified. The price of Grade A (tuberculin tested) milk as sold in Reading is one penny a quart higher than that of ordinary market milk. The figures which I show you are those of Grade A milk as it reaches the consumer in sealed and capped bottles, from three different distributors. The first series represents the results obtained between May 19th, 1922, and April 19th, 1923, from the examination of milk which had been sent by rail to the retailer. You will see that of thirty-four samples which have been examined during this period thirty-two gave counts which were within the certified standard and thirty-three were within the Grade A standard. It is to be noted that the standard for Grade A milk did not come into force until January of this year, and, therefore, these people were giving the public of Reading milk of the quality which is shown without any legal stimulus.

The second or third series cover a shorter period of time, January to March, 1923. They are, however, of great interest in that they show what can be done. The milk from which the samples in Series 2 were taken comes by rail to the dealer, and you will see that of 12 samples which have been examined up to date, nine were within the certified standard and twelve within the Grade A standard. The samples, the results of the examinations of which are shown in Series 3, were obtained from milk produced locally and brought directly to the dealers' premises. Of the thirteen samples which have been examined, ten are within the certified standard and thirteen within that of Grade A. The ultimate result, therefore, is that fifty-nine samples have been examined ; and fifty-one have been found to be within the certified standard, and fifty-eight within the Grade A standard. I may say that none of these dealers uses a brine cooler. But the milk, examinations of which are shown in Series 1, is brine cooled at the farm. Water alone is used for the cooling of milk on those farms from which Series 2 and 3 came. It does appear, therefore, that it is not an impossible proposition to provide the public with a raw milk from cows which do not react to tuberculin at a price which the consumers ought to be and are willing to pay, when they have realized its value. In my own house I have been getting this milk for more than twelve months ; it comes to me once a day, early in the morning. It is milk of the previous afternoon and I get no more until the following morning. There has been no sour milk in my house during this time, and there has been no need to boil the milk.

Other work which has been carried out at the National Institute for Research in Dairying has demonstrated two important facts quite clearly. The first is that where milk is properly produced and cooled at the farm to a temperature which may vary as much as seventeen degrees in the course of a year (45°F—62°F), and then is examined at the end of 24 hours, there is very little increase in the bacteriological content, provided that the temperature on arrival at the laboratory does not exceed 60°F. The second is that such milk can be guaranteed to remain sweet without use of any special methods of cooling for a minimum period of two days from the time of milking. Indeed, it is found that although the bacteriological content shows an increase at the end of twenty-four hours when the temperature of the milk has been allowed to rise about 60°F., that increase is not so great as one might have anticipated and the minimum period of sweetness which we have yet found has been thirty-six hours. When I speak of thirty-six hours sweetness, I mean that the milk was still apparently quite good at the end of that time, but had gone off at the end of forty-eight hours; that is to say, our tests were made every twelve hours. These observations were carried out during the year 1921, the hottest year we have had for a very long time, yet no milk remained sweet for less than 36 hours from the time of milking, although some of it reached us at temperatures as high as 88°F. In this paper I am only describing results obtained with samples of milk produced for commercial purposes. It is quite clear that if we are prepared to deliver milk of the quality which has been described, within a period of 24 hours, a once a day delivery during most periods

SERIES I.

GRADE A. (TUBERCULIN TESTED) MILK SENT IN CHURNS BY RAIL TO RETAILER. CONDITION ON DELIVERY TO CONSUMER.

Date of Examination	Age in hours.	Temp. of milk when tested in °F.	Number of Colonies in 1 c.c.	Presence or absence of B. Coli.
26 5 22	20	64	11,800	— 1. c.c.
2 6 22	20	72	68,000	— 1 c.c.
10 6 22	21	65	13,500	— 1 c.c.
16 6 22	21	62	8,700	— 1 c.c.
23 6 22	29	62	15,800	— 1 c.c.
30 6 22	29	58	18,400	— 1 c.c.
11 8 22	25	65	2,360	— 1 c.c.
18 8 22	26	64	230	— 1 c.c.
25 8 22	21	63	1,070	— 1 c.c.
1 9 22	21	55	6,400	— 1 c.c.
8 9 22	20	60	1,700	— 1 c.c.
20 10 22	20	52	19,600	+ 1 c.c.
28 10 22	20	46	14,100	— 1 c.c.
11 11 22	22	55	3,800	— 1 c.c.
18 11 22	20	49	16,400	— 1 c.c.
24 11 22	21	49	8,100	— 1 c.c.
2 12 22	20	50	7,500	— 1 c.c.
15 12 22	20	50	6,200	— 1 c.c.
22 12 22	24	49	2,900	+ 1 c.c.
6 1 23	21	51	1,230	— 1 c.c.
12 1 23	28	47	26,700	— 1 c.c.
19 1 23	29	47	6,700	— 1 c.c.
26 1 23	28	46	4,900	+ 1/10 c.c.
2 2 23	28	52	400,000	+ 1/1000 c.c.
9 2 23	28	48	13,800	— 1 c.c.
16 2 23	28	47	9,600	— 1 c.c.
23 2 23	28	47	19,600	— 1 c.c.
2 3 23	27½	48	14,800	— 1 c.c.
9 3 23	27½	48	6,100	+ 1/1000 c.c.
16 3 23	27½	49	21,800	— 1 c.c.
23 3 23	27½	50	14,800	+ 1/10 c.c.
30 3 23	27½	47	17,300	— 1 c.c.
6 4 23	27½	50	24,200	+ 1/100 c.c.
13 4 23	27½	53	14,700	+ 1/100 c.c.

SERIES II.

GRADE A. (TUBERCULIN TESTED) MILK SENT IN CHURNS BY RAIL TO RETAILER. CONDITION ON DELIVERY TO CONSUMER.

Date of Examination	Age in hours.	Temp. of milk when tested in °F.	Number of Colonies in 1 c.c.	Presence or Absence of B. Coli.
12 1 23	28	44	6,200	— 1 c.c.
19 1 23	28	47	28,100	— 1 c.c.
26 1 23	28	46	6,000	— 1 c.c.
2 2 23	28	52	10,800	— 1 c.c.
9 2 23	28	48	83,000	+ 1 c.c.
16 2 23	28	48	14,300	— 1 c.c.
23 2 23	28	46	13,200	— 1 c.c.
2 3 23	28	48	7,800	— 1 c.c.
9 3 23	28	48	17,800	— 1 c.c.
16 3 23	28	49	116,000	+ 1 c.c.
23 3 23	28	50	8,400	+ 1 c.c.
30 3 23	28	47	105,000	— 1 c.c.

SERIES III.

MILK PRODUCED LOCALLY, TAKEN TO DEALER'S PREMISES BY LORRY. CONDITION ON DELIVERY TO CONSUMER.

Date of Examination.	Age in hours.	Temp. on Testing °F.	Number of Colonies.	Presence or Absence of B. Coli.
6 1 23	30	51	4,900	— 1 c.c.
12 1 23	29	46	4,200	— 1 c.c.
19 1 23	28	47	16,600	— 1 c.c.
26 1 23	28	52	10,400	— 1 c.c.
2 2 23	28	52	30,400	— 1 c.c.
9 2 23	28	48	10,200	— 1 c.c.
16 2 23	28	47	17,300	— 1 c.c.
23 2 23	28	46	15,800	— 1 c.c.
2 3 23	28	48	10,600	— 1 c.c.
9 3 23	28	48	55,000	— 1 c.c.
16 3 23	28	50	3,400	— 1 c.c.
23 3 23	28	50	61,000	— 1 c.c.
30 3 23	28	47	11,200	— 1 c.c.

SUMMARY.

Series.	No. of Samples.	Certified Standard 30,000		Grade A. Standard 200,000	
		No. within standard.	No. above standard.	No. within standard.	No. above standard.
1	34	32	2	33	1
2	12	9	3	12	0
3	13	10	3	13	0
	59	51	8	58	1

of the year will suffice. If, in addition to this we are prepared to keep our milk cool on its journey from the farm to the dealer's premises, it is possible that a once a day delivery might suffice even in the summer months.

There is no doubt that a fresh milk supply is a practicable proposition in this country if we choose to make it so. The first element of success is a more widespread knowledge of the proper methods of handling milk. That this may become possible, much greater support should be given to the Agricultural College than is the case at present. I trust that you will agree with me that the practicability of supplying the public with a sound fresh milk supply is now an established fact, which is, after all, a very great argument for maintaining its existence. There are, however, other collateral arguments to which I should like to be allowed to direct your attention.

Hardly a day passes but we have visitors at Reading, farmers, dealers and others who come to see what is being done. These are the signs of a new spirit within the industry, a frank acknowledgment that there is something to be learnt and a willingness to learn it. The same spirit is found on those farms on which better methods of handling milk have been introduced. The labour improves in quality in every direction, and we shall better results in a few years' time than we get now. It would be difficult to maintain quite the same spirit if each man did not feel that the final success was immediately dependent upon his particular effort.

Within the industry itself, the production of milk of the standard of cleanliness which is necessary for the successful sale of fresh milk will have far reaching effects in directions other than that of the whole milk trade. If, for example, we turn to the condensed milk industry, we find that such things as blown tins of condensed milk are not unknown. What losses the condensed milk industry incurs as a result of such a condition I am not in a position to say. But I imagine they are sometimes not inconsiderable, and when such a case was investigated by Miss Hiscox at the

National Institute for Research in Dairying, the fault was found to be due to two types of yeast which were certainly not in the milk as it came from the cows' udders. I have often wondered what savings might be effected in this industry if it were in a position to make use of a really clean milk, and how far such savings, possibly influenced also by a simplification in the methods of handling, might improve the nutritive value of the product. Even in the biscuit industry it appears to be true that the cleanliness of the milk is an important factor in producing a satisfactory article. When we turn to such a problem as cheese making, we find on every hand the influence of clean milk upon the final result, and the deleterious effects which the presence of dirt in the milk may produce.

It is improbable that there is any future in this country for second and third grade dairy products since they must compete with products from overseas where the costs of production are lower than they are here. On the other hand, there is always a market for the best, and one of the first essentials for producing the best is that we shall start with clean milk. I appeal to you, therefore, to keep the market for raw milk open, because we know it can be supplied clean, and because in the doing of it we are helping to promote the highest interests of those who are responsible for this work and are also assisting all those who are engaged in collateral industries.

THE CHANGES WHICH OCCUR IN THE DIGESTIBILITY AND NUTRITIVE VALUE OF MILK ON HEATING.

By Professor J. C. Drummond, D.Sc., F.I.C.

The enormous practical importance of the widespread introduction of methods involving heating for the preservation of perishable foodstuffs has tended to divert attention from other aspects from which this matter may be viewed. There is, furthermore, a danger that the commercial interests behind the exploitation of these processes will be guided by motives which are little influenced by the opinions of the impartial external authority, unless they are obviously and economically advantageous. To the scientist familiar, on the one hand, with the modern processes of canning, pasteurisation, and desiccation, and on the other, with the extraordinary complexity of the living cell or of biological fluids, such as milk, it is a source of wonder that the nutritive value of foods is not more vastly changed than it appears to be during these treatments. Nevertheless, it is daily being brought home to him that the changes which do occur are not only much more numerous than were formerly suspected, but are also of far deeper significance.

The artificial conditions which our civilisation has built up, particularly in the large towns and industrial areas, render necessary many forms of the pre-treatment of foods, if these are to reach the consumer in a hygienic form, but is not sufficiently appreciated that the movement is almost solely in the one direction, away from nature, and that there may be a cumulative effect.

In discussing the vitamins, to which I will make further reference later, and their significance in the nutrition of the masses, one freqently encounters the argument that the food consumed in Western Europe is of so varied a character that deficiencies in one component, occurring either naturally or caused by artificial treatments, tend to be made good by the supplies contained in another constituent of the ration. No more dangerous belief could be held, and if the tragic story of the peoples of the Central Powers is not sufficient to demonstrate this, a single example taken nearer home may serve.

During the War the populations of many of our larger northern towns were, as industrial workers, being as well fed as any people in the country, and, although probably restricted in some directions, were able to obtain a diet quantitatively sufficient and reasonably varied. In spite of this, the incidence of several sharp outbreaks of typical scurvy when the potato crop failed demonstrated that here were cases of large masses of individuals living on a varied diet but, nevertheless, in the borderland of one of the severe deficiency diseases. It is unfortunately only too easy to introduce one modification of the food after another without appreciating how far along the path towards a wholly artificial food supply we have already progressed, or how slight may be the change which just turns the balance.

It is, therefore, full time that the voices of those who call attention to these facts should seriously engage the ear of the public, and that the proposals of those who

advocate a return to more natural conditions should have sympathetic consideration.

An example in which, after some opposition, this has been done with the most striking results is provided by the recent developments in pig-keeping. Years upon years of agricultural practice have seen modification after modification of the method of housing and feeding pigs introduced, until gradually almost all resemblance to the normal condition under which pigs live in nature had become effaced. Housed in a small space in styes of good, bad, or indifferent type, and fed on food mixtures which modern research in nutrition has shown to be unbalanced from the point of view of many natural, but essential, constituents of foodstuffs, pigs were produced which were regarded as satisfactory from every standpoint. In spite of this, a few pioneers began to appreciate how far from the natural conditions they had strayed and the open air method of feeding pigs on grazing was re-introduced almost as a novelty. Their convictions received adequate support from the scientific experiments which Capt. Golding, Dr. Zilva and I made, and in which we demonstrated the extraordinary value of such a method of feeding. Within a few years there has been a most remarkable change, and to-day, all over the country farmers are reverting to more natural methods. This example well illustrates the attitude which scientists should adopt towards such a debated question as the compulsory pasteurisation of milk. Whilst being the last to deny the benefits which such a process has yielded in the past, we insist in regarding it as a temporary departure from Nature necessitated by existing conditions, but to be given up as soon as it can be safely dispensed with.

The grounds for this opinion are that all unnatural treatment of foods should be excluded as far as our cultural customs will permit, because even to-day, with the wide advance in our knowledge of the biochemistry of foodstuffs which has taken place in recent years, we are appallingly ignorant, although deeply sensible, of the complexity of such biological materials.

I fear I have devoted so much time to these general matters that it leaves me little opportunity to treat the actual subject on which I am supposed to be speaking. I have done this intentionally, because the problem is a broader one than merely that of heating or not heating milk; furthermore, to deal adequately with the changes which are believed to occur in the heating of milk would occupy many times the period that has been allotted to me.

I will first consider very briefly those remarkable substances, discovered by Professor Hopkins in 1912, and known as the vitamins. There is a general impression in people's minds that these essential factors are entirely destroyed in the heating of foods in which they naturally occur. This view requires modification in the light of recent and confirmed observations. There are three substances in this group of food constituents, and for convenience they are labelled A, B, and C. Of these, B, or the antineuritic factor, is apparently stable under the ordinary conditions of heating of milk and suffers practically no loss. The other two, A, possibly identical with the anti-rachitic factor, and C, the anti-scorbutic substance, are not destroyed by heat, but are rapidly inactivated by oxygen, particularly when the temperature is raised. The amount of all these factors present in milk is dependent on the amount present in the food of the cow, or mother, and the proportion of A or C destroyed during the heating of milk will depend on the amount of exposure to oxygen which occurs, and the temperature at which it is exposed. As far as the results of experiments show, although these are less definite than might be desired, the amount of C lost during such process is usually less proportionally than that of A. This may be partly because it is apparently more readily inactivated by oxidation, and partly because milk is not a particularly rich source of C naturally. In order to damage the vitamins in milk as little as possible during any heating process it is necessary to employ as low a temperature as is permissible, and to avoid all unnecessary contact with air. It is for this reason, that pasteurisation by the "holder" process tends to cause less damage to these essential substances than pasteurisation by the "flash" method.

As far as can be told, from the available evidence, however, the loss of the substance A is not serious during the pasteurisation, condensation or drying of milk.

I now pass on to deal with an entirely different aspect of the effect of heating milk. It is common knowledge that milk is clotted shortly after entering the stomach

by the action of an enzyme rennin present in the gastric juice. The clot that forms may vary in character from a hard almost leathery mass to a fine suspension of minute flocks. A great amount of study of the clotting of milk has been made, and it has been shown that, temperature, reaction and other conditions being constant, the time of clotting and the size of the clot is mainly controlled by the concentration of ionisable calcium salts present. In the presence of a normal amount of ionisable calcium salts cow's milk forms a stiff clot rapidly, but if these are reduced the clot forms more slowly and is finer.

Now, there is very definite evidence that during the heating of milk a change occurs in the form in which calcium is present. The nature of this change is imperfectly understood as yet, but it is easily demonstrated that heated milk clots more slowly and forms a finer clot than the untreated sample. For this reason, many authorities on infant artificial feeding prefer dried milks to fresh since they hold that the digestive system of the infant is more readily able to deal with the fine clot which the former yield, and which they hold more closely resembles the fine clot which human milk is believed to form. Some studies one of my colleagues and I have recently made, indicate, however, that the matter is probably not so simple as it at first appears, and that the disturbance of the complex colloidal system of milk during heating is so deep that the comparatively small question of the size of the particles of the clot may be of relatively little account.

An example of this is provided by certain forms of dried milks which have been prepared by what is known as the "roller" process. In this method of preparation the milk suffers exposure to a temperature above boiling point for a very short time, and yet the final product shows great changes in its main characteristics. Practically all the coagulable proteins have been rendered insoluble, and the delicate emulsion of fat has been so damaged that on reconstitution almost all the fat separates as a butter-like mass instead of as cream. If these and other obvious changes have occurred how great is the probability that many other alterations, as yet undetected or of unknown significance have also been induced! From studies of the digestibility of milks in the living animal by methods which enable each stage in the passage of the various constituents through the alimentary tract to be observed accurately, we have been deeply impressed with the far-reaching effect of many of the apparently negligible changes which occur in milk during heating, especially that which occurs during some forms of drying. Our experiments have, as yet, progressed a very short way, and it is too early to bring forward any definite views, apart from the opinion already firmly established in our minds that it is impossible to heat a delicately balanced colloidal complex such as milk without bringing about very many changes. Some of these changes are already known to be undesirable, even if they are usually slight, such as the loss by oxidation of the indispensable vitamins; the significance of others, such as the changes in the character of the clot formed in the stomach, is as yet imperfectly understood, whilst lastly, there are the many changes as yet undetected which later knowledge may show to be as important as those which are now receiving attention. The aim must be to supply milk to human beings as it is given by the cow.

THE EFFECT OF HEAT ON SOME PHYSIOLOGICAL PRINCIPLES IN MILK.

By S. S. Zilva, Ph.D., D.Sc., F.I.C.

Few people will dispute the advisability of pasteurising milk produced under some of the conditions prevailing at the present time. An excellent nutrient medium such as milk turned out under anything but aseptic conditions must contain a great number of organisms—some pathogenic, others harmless — when it reaches the consumer. Pasteurisation is undoubtedly a good means of keeping low the number of such organisms in milk. However, when the value of a food like milk is fully considered it is difficult to get reconciled to the notion that pasteurisation is an ideal mode of treatment. Researches in the province of nutrition have made it quite clear that the nutritive value of an article of food does not entirely depend on its calories, its inorganic constituents, or even on the biological value of the protein it contains. It is now known that it depends to a great extent on some physiological principles the character of which is only vaguely known to the scientific men of the present day. Milk holds a unique place in this respect. It is intended by nature to be the sole food of the young

at a period of life when, as our present knowledge of nutrition shows, these physiological principles are even more in demand by the organism than during the period of adult existence. It is, therefore, to be assumed, and it has, indeed, been shown to some extent, that a great nutritive function is fulfilled by some of these so-called biological factors present in milk. Unfortunately, all the biological principles of milk so far known are thermolabile. In order to illustrate the actual process of inactivation of such principles by heat, I am going to discuss the effect of heat on the behaviour of the enzyme peroxidase in milk, a subject I had the opportunity of investigating some years ago.

Peroxidase is an actual constituent of fresh cow's milk. It is usually demonstrated by the addition of hydrogen peroxide and p-phenylenediamine to the milk. These reagents in the presence of the enzyme produce a blue-grey colour. When milk is heated beyond a certain temperature this reaction is no more perceptible. At lower temperatures, however, the inactivation is gradual and can be shown to proceed as a monomolecular reaction; namely, a constant is obtained when the formula $K = \frac{1}{t} \log \frac{C_1}{C_2}$ is employed where t = time, C_1 = original concentration and C_2 = the concentration at the time observed. At such temperatures the concentration of the enzyme can be estimated at different times colorimetrically against a set of standards containing various proportions of fresh milk diluted with boiled milk in which the enzyme has been inactivated. The table gives some experimental data in the case of peroxidase in milk the velocity of inactivation of the enzyme becomes marked at about 67°C – 68°C and at about 73°C the inactivation proceeds so fast that it may be considered to be almost "instantaneous." The curves show the behaviour of the enzyme at three temperatures namely, 68.9°C. 70.07°C. and 70.95°C. You will see that at the last temperature 95% of the total peroxidase is destroyed in 20 minutes whilst at the next temperature, which is only one degree lower, the same amount of the enzyme is destroyed in 80 minutes. At 68.9°C. it takes 120 minutes to inactivate only 80% of the enzyme. A temperature of 65.5°C produces no perceptible destruction. From these figures one can further calculate the constants by the use of the formula of the monomolecular reactions, and it is seen that the constant which is 0.02698 at 70.95° gradually falls to 0.005066 at 68.9° C. The mean temperature co-efficient obtained by these figures comes to 2.231 per 1° C.

Peroxidase is not the only principle which behaves towards heat in this way. This process of inactivation has been found to be characteristic of other physiological principles. It is evident, therefore, that when one speaks of an enzyme as being destroyed at a certain temperature, what is really implied is that at that temperature the rate of inactivation is very high, so that the greater part of it is destroyed in a very short time. The inactivation proceeding as a monomolecular reaction, it is to be expected on theoretical grounds that it takes place extremely slowly even at ordinary temperature, and that at high temperatures the inactivation is not entirely complete. Both these computations are, however, beyond the possibility of experimental verification and, therefore, do not merit practical consideration. Although peroxidase is inactivated markedly at a temperature which is outside the limit of heating employed in pasteurisation, we are by no means sure that this applies to all the physiological principles present in milk. Complement, for instance, is destroyed at 56° C.

The biological properties of milk, as far as our present knowledge of the subject goes, may be divided into three main classes, namely, the enzymes, the substances concerned in the production of immunity, and the vitamins. Opinions differ as to the value of the first two classes of substances. Some maintain that they are present in milk with a definite purpose and that the enzymes are concerned in the metabolic processes of the young organism, whilst substances of the second class are instrumental in imparting immunity in the early stages of life. Others, on the other hand, consider that these factors are merely waste products derived from the blood by filtration. Neither side has yet succeeded in proving its theory to the satisfaction of the other. As far as the vitamins are concerned there is very little doubt now that their presence in the milk fulfils definite and important functions, especially when milk forms the sole food in the nutrition of the infant. Both clinical and laboratory investigations have amply proved

this. This alone plainly illustrates the fact that the value of milk does not entirely depend on its chemical ingredients. When one further takes into consideraton that the conception of vitamins was only formulated less than 20 years ago, it is not unreasonable to suspect that there are yet other illusive principles in milk which cannot be detected by means of ordinary analysis—principles sensitive to technical manipulation. If we are, therefore, to preserve all the qualities of nature's perfectly balanced food we must strive to produce it in such a way that it would reach the consumer clean and free from infection, but otherwise untampered with.

Although pasteurisation may be regarded as the lesser of two evils when one considers the risk run by consuming fresh milk produced under average conditions, it is, nevertheless, highly commendable to maintain and encourage a market for fresh milk which is produced under hygienic conditions. Efforts in the production of clean fresh milk may lead one day to the possibility of discarding pasteurisation without running the risk of infection. Most means which destroy harmful organisms also destroy its biological properties. The obvious problem before us is, therefore, not to tamper with the milk, but to devise means compatible with economic exigencies which will obviate the infection of milk.

A DEMONSTRATION OF SOME OF THE CHEMICAL CHANGES WHICH TAKE PLACE IN MILK ON HEATING TO VARIOUS TEMPERATURES.

By Captain John Golding, D.S.O., F.I.C.

A sample of fresh milk was divided and one part was heated.

At 60° C. (140° F.) a skin began to form on the surface of the milk in the presence of air. The condition of the fat was modified, and an obvious difference in the cream layer was observable after heating.

The effects of heating milk upon the time of coagulation by rennet was demonstrated in an apparatus originally designed by Mr. John Benson and modified by Mrs. A. T. R. Mattick. The apparatus consists of a double walled insulated vessel holding about 300 c.c. fitted with an insulated cover, and with a hole 1 m.m. in diameter in the base.

The test was carried out with 250 c.c of milk with an acidity of 0.21 per cent. This was brought to a temperature of 84° F., and 1 c.c. of rennet, diluted with twice its volume of water was quickly added, and the mixture stirred rapidly for ten seconds and then transferred to the experimental vessel. At first a steady stream of milk ran through the hole, but gradually became interrupted and finally ceased. The time of the test was recorded by a stop watch, and denotes the number of minutes and seconds which elapsed from the moment when the rennet was added to the milk until the last drop fell from the hole.

By this method fresh milk was compared with milk which had been heated to 145-150° F. (62.80° C-65.5° C.) for ½ hour, and, in a third experiment, with milk heated to 160° F.

The results obtained during the demonstration were that the time of test for the unheated milk was 4½ minutes, that heated to 145-150° F. for ¼ hour was 7½ minutes, while the coagulation of the milk heated to 160° F. (71.1° C.) for ½ an hour was not complete when the meeting ended.

A phenomenon as yet unexplained, which occurred in the course of preparation for this demonstration, was the apparent "speeding up" of the time of coagulation of perfectly fresh milk immediately after heating to 145-150° F. with subsequent cooling to 84° F. On standing, however, the usual retarding of the time of coagulation was observed. The milk actually used in the demonstration was heated on the previous day.

The destruction of enzymes in heated milk was demonstrated by the following tests :—

Schardinger Reaction. A test tube of heated milk retained the colour of methylene blue in the presence of formaldehyde and the absence of air at 45° C., but from unheated milk, treated with the same reagent, the colour was discharged, indicating the presence of a substance which, in the presence of formaldehyde, has the power to bleach methylene blue, but which is destroyed by heat.

The presence of peroxidases in unheated milk and their absence in heated milk was demonstrated by adding ortol and hydrogen peroxide to both samples, a deep red colour being produced in the unheated milk.

The temperature at which these peroxidases are destroyed was demonstrated by adding 0.3 c.c. of 1 per cent. solution of hydrogen peroxide and 0.25 of a 2 per cent.

solution of paraphenylenediamine to 10 c.c. of milk. This test gave a blue colour, which, however, was so intense in the unheated milk that it was necessary to dilute it with four times its volume of boiled milk, to get a sufficiently pale colour for comparison. Various volumes of this dilution were taken, and in each case made up to 10 c.c. with boiled milk before adding the reagents.

The samples tested had been heated for half an hour to temperatures varying between 145° F. and 160° F. While no visible destruction could be demonstrated at the lower temperature, a very marked destruction was shown at 160° F.

DISCUSSION.

The Chairman in inviting discussion, said the question seemed to be summed up in the point, "To pasteurise or not to pasteurise?" Perhaps some exponent of pasteurisation would like to start the discussion.

Mr. Ben Davies said he would like to speak as an advocate of pasteurisation. He confessed that he had attended the meeting hoping for a little fun, and Dr. Williams had rather disappointed him. He wondered what was the impression left on the minds of the public when they heard the sort of papers which had been delivered that afternoon. They heard a great deal about tubercle in milk. Just what was the danger? Did tubercle kill babies?

The Chairman said that that question had not been referred to by any of the readers of the papers.

Mr. Ben Davies said the Chairman had invited members of the audience to speak on the question of pasteurisation.

The Chairman said he thought the discussion must be in relation to the papers which had been read, and that an entirely new subject could not be introduced.

Mr. Ben Davies, continuing, said that Dr. Williams had given his audience to understand that it was a possible thing to get a supply of milk from tubercle-free cows at moderate cost. What was the cost? The cost of attempting to get a supply of tubercle-free milk was that the milk of tuberculous cows was simply passed on to somewhere else. Tuberculous cows were taken out of selected herds, sold in the open market, and their milk continued to be used. That was not his conception of public health legislation, or of dealing with the subject. As a matter of fact, the tubercle question was a very trifling one with regard to infant life.

The Chairman said, if that was the case, the point might be dropped, and something discussed which bore on the papers which had been read.

Mr. Ben Davies said he thought it was rather unnecessary for the Chairman to invite remarks on the question of pasteurisation if, as soon as the question was raised, he ruled it out of order.

The Chairman said that Mr. Davies was talking about the tubercle question, which had not been raised at all.

Mr. Ben Davies said the reason for pasteurisation was to eliminate any chance of tubercle in the milk supply.

The Chairman said that was not altogether so.

Mr. Ben Davies, continuing, said one of the great reasons for it was to eliminate pathogenic organisms in the milk supply, of which tubercle was the great bugbear which was held up. While they were waiting for the ideal milk to come along in sufficient quantities, what were they going to do about it? He felt himself in a great difficulty because he did not know when he was going to transcend the Chairman's ruling. Supposing such milk did meet all the requirements of public health people, the quantity was entirely limited; whereas an absolutely safe supply of milk was obtainable forthwith if the method of pasteurisation was adopted. No test had been brought forward that afternoon which indicated that there was even a scientific objection to pasteurisation. He was still waiting for something more than a mere suggestion that pasteurisation had any deleterious influence on the milk supply. The fact of the matter was that when one came to apply a test which did matter, namely, the test of actual use in public life, it was found that there was immense enthusiasm amongst those who used it, and that tests, such as those as had been made that afternoon, and which nobody really understood, had very little bearing on the question.

Dr. John Donald said it was not so much a matter of bacteriology as of biochemistry. The latter science was only in its infancy, and he thought it would yet be proved—justifying what experience suggested—that there is a vital something in milk which is detrimentally affected by heat. What many felt was that what was required for a child, especially a delicate child, was a milk that had not been tampered with by heat; or, in other words, raw milk; and that essential nutriment, physical, mental and spiritual, was to be obtained from raw foods, especially milk. After all, when one came to think of it, man was accustomed only a few thousand years ago to eat raw food. In his opinion, the present day cooking of our food

had something to do with our being to some extent a C.3 nation. The incidence of disease was falling in all respects, with the exception of three diseases, namely, cancer, appendicitis and tuberculosis. The figure of the incidence for tuberculosis was as high as ever, and he believed it was chiefly because of food deficiency, in quality, not quantity. In the present day of gas stoves and electric heaters, women were more inclined to go in for faked up articles of food. There was no doubt about the fact, though it could not yet be substantiated by the laboratory, that there was a vital something in milk. Three vitamins were referred to, but there might be, and probably were, twenty vitamins in milk and green vegetables. It was all very well to say, for example, that vitamin B was not destroyed at boiling point, but he was convinced that in fresh green vegetables there was something more than vitamin B about which nothing was known, and which is destroyed at that temperature. If a child were continuously given pasteurised milk he would soon get sick of it, first because of the flavour of cow dung in solution, and also because of the cooked taste. If, however, a child were given raw clean Grade A milk, he enjoyed it and retained a relish for it. Dirty milk must certainly be pasteurised, but if milk is clean, what on earth did we want to pasteurise it for?

Mr. Wilfred Buckley, C.B.E., said probably all parties would be in agreement if they could all get milk as it was drawn from a healthy cow. He thought that one of the errors which was made in the discussions on the subject was in contrasting pasteurised milk with milk as it was drawn from a healthy cow. There was nobody keener in the country about raw, fresh milk than himself. His own opinion was that if an equivalent to certified milk could be obtained he doubted if there were many people who would question using milk of that description. Certified milk or Grade A. tuberculin tested milk, however, could not be obtained at the moment to a large extent. Therefore, they had to make up their minds how they were going to treat the present general supply of milk whilst waiting for that milk which they all desired to get, namely, milk as it left the cow's udder. He was not a scientist. Enough had been heard that afternoon to show that in regard to pasteurisation there were many things not understood. On the other hand, there were many things which were known, and it seemed to him that the error lay in arguing for pasteurisation on the one side and perfect milk on the other. As there was not a big supply of the kind of milk which everyone desired, they had to make up their minds as to what was the best thing to do for the nation at the moment and for the immediate future. He was as great an advocate as anybody of raw milk when it could be had in as perfect a state as possible, but he thought a great mistake would be made if pasteurisation was considered as a menace. In his opinion it was necessary for the bulk of this country's milk to be pasteurised. The United States were certainly in advance of this country on the milk question. Taking the twelve cities of the United States with a population of over 500,000 inhabitants, it would be found that 95 per cent. of the milk was pasteurised.

Dr. R. Dudfield asked to be permitted to correct two statements which had been made. Mr. Ben Davies had said that anybody finding a tuberculous cow in a herd would pass it on to the general market. Mr. Davies had forgotten the provisions of the Milk and Dairies Act of 1922. Anybody who passed a tuberculous cow into the general market for use as a milch cow would stand in jeopardy of the law and of a penalty of £100. The second statement he wished to correct was that tuberculosis was running rampant in the same way as cancer, and in fact was increasing. If the gentleman who had made that remark had studied the Registrar-General's returns for the last few years he would have found that tuberculosis was following a course just opposite to that of cancer. Whereas cancer was going up tubercle was going down.

Dr. Donald said the mortality was going down, but not the incidence.

Dr. Dudfield said he begged to differ. The incidence of the disease was going down, as well as the mortality. He thought everybody must agree that milk was intended to be taken as it was delivered either from the cow or from the mother. Therefore, they ought to try to give their babies milk as Nature intended they should have it. It had been urged that afternoon that it was an impossibility at the present moment to drink milk in such a condition, because it would be either dirty or diseased. He put it to the meeting, was not any vaunting of pasteurisation (and he said it in spite of medical experience) a shirking of the whole question? Were not they rather relying on pasteurisation to undo, or prevent, the mischief which might arise from neglect in production? His contention as a Medical Officer of Health was that their aim should be, not to perfect processes of pasteurisation in order to undo the evil which had happened in production, but that they should, in the first place, see that the herds were healthy, and in the second place see that the milk was taken from those cows under conditions which were as near the ideal for cleanliness purposes as possible, and, thirdly, see that the transport was improved so that the milk was brought to the consumer as quickly as possible under conditions which would not favour the growth of germs. If that were made

the aim of the milk trade generally there would be absolutely no need for pasteurisation. He believed that cooked milk was not good for babies; they ought to have it in its natural condition.

Mr. Horace L. Roberts, F.R.C.V.S., said, as one who took a certain amount of interest in poor people, he had been very much impressed with Dr. Williams's statement that the production of a better quality of milk did not mean an increase in the price of milk beyond a penny per quart. Turning to the question of pasteurisation, he had been asked as a country veterinary surgeon to interview certain Members of Parliament who were greatly interested in the special Designations Order, 1922, which Order laid down that a double pasteurisation was not permitted. He had been informed that a double pasteurisation killed the vitamins, but he had heard that afternoon that excessive cooking did not always kill them. That had a very important bearing on the future Designations Order which no doubt would be produced, and he hoped that the Chairman might inform the Minister of Agriculture that doctors had stated that vitamins were not killed by double pasteurisation, because it had been almost an instruction to the Ministry of Health, in drawing up the particular clause in the Designation Order, to prohibit the double pasteurisation of milk. As a veterinary surgeon he would ask the authorities, in considering the whole question of germs in milk, also to take into account the methods by which the cow might be dealt with on the premises. The great stumbling block in the production of a purer supply of milk was, in his opinion, the expense in producing that milk to the consumer. The farmer was put to considerable expense in having his cows examined and tested in order to produce a better class of milk. If, as had been suggested, a certain sum of money were put aside for that purpose, he thought it would not be long before this country had as good and as pure a supply of milk as America; but for the present he supposed they would have to rely on the various methods of pasteurisation, and be as clean as possible in the handling of the milk on the farm.

Professor Drummond said he hoped he had not given the impression that recent work had shown that the vitamins were untouched in pasteurisation. The earlier view had been that they were entirely destroyed during the heating of milk. He had said that view must be modified. One of the substances was not damaged; the other two were. They were not destroyed by heat; but they were destroyed on exposure to oxygen or air. Certain processes would not necessarily destroy the whole amount present, but the amount destroyed was proportionate to the temperature, time and extent of exposure. All he had said was that the old idea that heat destroyed those substances needed modification.

Mr. Buckley asked if Professor Drummond could give his opinion with regard to double pasteurisation.

The Chairman said he had not gathered that anything in the lectures had pointed towards a change in the present Orders in the direction of allowing double pasteurisation. Perhaps Professor Drummond would state whether his researches led him to think that double pasteurisation might not be harmful.

Professor Drummond said there were no definite experiments on that point, but, as Dr. Zilva had shown, the destruction of biological principles followed certain definite laws, and in the destruction of biological principles, such as the vitamins, the factors which determined the destruction were the temperature, the time of exposure at that temperature, and, more particularly, the amount of contact with oxygen or air which occurred at that temperature. The effect of double pasteurisation must be that, if the temperature and the degree of aeration were the same, the extension of the time of exposure would increase destruction.

Mr. Allan Skelton said the only point he desired to make with regard to pasteurisation was this. In going about the country, giving lectures on clean milk production, he had always brought the argument forward that any step taken to make milk so-called "safe" after it had reached the consumer must be, from the producer's point of view, a retrograde step, because it would tend to make producers of milk more careless than many of them were at present. If producers realised that pasteurisation, or any other form of treatment of milk, would make it safe, they would be more careless than they were at the present time, and therefore, there would be much longer delay in getting that clean supply of raw milk which was so much needed. He maintained that the clean supply of raw milk was rapidly growing and would continue to grow, provided producers did their duty. It could be produced to the public at such a very small extra cost over and above the milk ordinarily sold that he did not think there was any real argument in favour of the statement that the country had to wait for many years before it would obtain such a supply.

Dr. Robert Mond said that it had been said that the man who heated good milk was a fool and the man who heated bad milk was a knave. He did not think the case could be better put. At the Infants' Hospital he had taken a great interest in the question of trying to work out the best method of preparing pure raw milk. If the milk was heated, the lime contents were reduced and that lime was essential to the building up of the bone structure of the infants, the albumen was coagulated and according to

the temperature employed over a certain heat, this favoured the growth of certain putrefactric bacilli. If the defections were examined, they could trace many of the ailments the babies suffered from to the way in which the milk had been abused. As a matter of fact, heated milk kept at summer temperature 24 hours was one of the best things he knew of for killing babies. They had carried out a number of experiments, feeding kittens on this milk, and the kittens had died at the end of a fortnight. Babies could be saved by giving them raw milk, because nature had arranged that acid bacilli should be present in milk and these were a safeguard of life. Now he took it that the real reason why people scalded or pasteurised milk was a very simple one. Milk easily became sour by keeping, and pasteurising it was the most convenient way of preventing it getting sour.

Dr. Harold Scurfield agreed with Mr. Buckley when he said there was room at the present time for both pasteurised milk and clean milk. Most of those who understood the papers would agree that the case with regard to the harm done by the "holder" process of pasteurisation must be considered as not proven. The three things mentioned by one of the readers of the papers were the enzymes, the immune bodies and vitamins. No doctor knew the purpose of the enzymes. The immune bodies were intended for the calf, not for the human infant. The human mother had different immune bodies with which she ought to feed her baby in the natural way. Therefore the immune bodies could be dismissed. The vitamins, by the pasteurisation process, with the exception of the anti-scorbutic, remained practically intact, and all that was required was a little orange juice for the unfortunate baby that had to be bottle-fed. When one came to children at a later stage, it was not a natural process to give them cow's milk. Cow's milk for a human being of any age was artificial. It was an extremely good artificial food, and had been used for thousands of years, and he would remind the audience that there were other artificial foods, such as butter and cheese. He would also point out that dry curd had been in use for hundreds and thousands of years, and formed a very valuable food for the Tartars on the steppes of Russia. Therefore, they must keep a more or less open mind and treat milk and dairy products in a strictly scientific way. It was no good talking about a vital something. The only live things in milk were the germs which got in it from outside. Milk was sterile when manufactured by the mammary gland. There was no justification for a scientific person talking about a vital something in milk. There were certain chemical substances in milk, the use of which was not known. Scientists were extremely ignorant about the whole thing. They did not know the use of rennet. They did not know why there was rennet in an infant's stomach to clot the milk. With regard to a remark of a previous speaker, he did not believe the milk supply of America was very much better than the supply in this country. Mr. Buckley had said that the Americans pasteurised 97 per cent. of their milk. Therefore, it was not a question of raw good clean milk in America. If he could get good clean raw milk he would certainly prefer it to any other, but he could not obtain it where he was living.

Dr. Stenhouse Williams, in replying to the discussion on his paper, said he thought that the discussion had wandered a little away from the point. Some of the things which had been said with regard to pasteurised milk did not meet with his approval. There was no question about it that much had been done to help the milk supply in this country by pasteurisation. He thought it should be admitted how little was known about milk. Mr. Ben Davies had said he was disappointed he had not raised any contentious subject, but his object in reading his paper had been to bring home the fact that it was possible to give a raw milk supply to the people of this country. He had thought that that was the first fundamental thing to do, and that when he had said that he had said enough. He thought he had proved the point that that supply could be given, and he wanted his hearers' help to spread that point in future.

On the motion of the Chairman, a vote of thanks was accorded to the readers of the papers and to Captain Golding for his demonstration.

NOTES ON BOOKS.

Wages in the Coal Industry.—By J. W. F. Rowe. London: P. S. King and Son, Ltd.

We congratulate Mr. Rowe on having given us a carefully arranged and well digested study regarding wages and wage conditions as affecting an industry, not only of primary importance, but also aptly illustrating the bearing of such factors as favourable or unfavourable position (rent factor in the sense that Ricardo developed Adam Smith's preliminary study as to rent), and the bearing of wage capital, in Mallock's sense of the term (that aspect of capital which enables preliminary work to be done, which will not itself support those who do the work). In addition the coal industry affords admirable illustrations of the incidence upon wages of that which is often called the rent of ability.

It may be pertinent to point out that Mallock has put forward an argument which tends to merge capital and rent of ability in the concept of "intellect," as manifested in the special ability of making the work of others more fruitful,

and, finally, all capital, in its essence or reality, is regarded by Mallock as the control of intellect over labour, or "Industrial ability"; and not something definitely concrete, as in the Marxian view. (Labour and the Popular Welfare, by W. H. Mallock, London, 1894, Adam and Chas. Black, pp. 129 to 135; also chapter III., and the Appendix.)

Mr. Rowe goes a little beyond his strict text of "Wages in the Coal Industry," by his reference (p. 131) to advanced thinkers who consider it "wrong for any man to work under a system by which the proceeds of his labour go to individual investors of capital," and he seems almost to tolerate enforcement by trades unions (pp. 38 and 39, with footnote 1), but in other places, he appears to promulgate the view that enforcement, if any, should be a function of the Government. The counter proposition, unfettered individual bargaining, receives rather scant consideration. It may be well to remember that prior to the repeal of the combination laws in 1824, individual bargaining was the practice in this country, and as trades unionism arose almost immediately after the repeal, we have about a century of experience on which to base a study.

Mr. Rowe promises well as an exponent of economic facts; his text being lucid and his graphs well plotted; so that students of what is, perhaps, the most difficult, yet the most important, branch of study may hope to hear more of him.

COCONUT INDUSTRY IN SOUTHERN MEXICO.

One of the most important industries along the coastal sections of the southern States of Mexico is the production of coconuts. The growth of this tree is natural to the soil and climate of the region, and when coconut groves are once started they need very little care.

In order to lay out a coconut plantation it is necessary to have sandy, loamy soil, lying in the vicinity of the seacoast. The first bearing of the coconut trees takes place during the fifth year and full bearing is reached during the sixth year. Groves situated some distance from the seacoast do not bear until the ninth or tenth year. The trees then bear for about 50 years, and after this period of production the yield gradually decreases.

From a report by the United States Vice-Consul at Manzanillo it appears that there are at present in that district about 60,000 coconut trees in full bearing, and approximately 40,000 more trees that will bear within the next three or four years. It is estimated by the manager of one of the large haciendas in the State of Colima that the annual production of coconuts from one tree is fron 50 to 60 nuts, and that the total production of all the trees in the State of Colima is approximately 2,500,000 to 3,000,000 nuts.

Of the annual production, fully 90 per cent. is consumed as a fruit and only a small percentage is used for the manufacture of copra. The majority of the nuts used as fruit are sold to the markets in Guadalajara and Mexico City.

When the nuts are to be used in the manufacture of copra, they are left to mature and drop from the trees. The nuts are then split open and are left to dry in the sun for seven or eight days. Following the drying process the meat is then removed from the shell. It takes about seven nuts to make a kilo of dried copra (about 2.2 pounds). The dried copra yields about 50 per cent. oil, which is used chiefly in the manufacture of soap and other toilet articles.

At present the coconut oil is being used in the manufacture of butter substitutes, other edible fats, and toilet articles, the use of which is gradually increasing in importance, and which would naturally tend to make this industry one of the most important, agriculturally, in the coastal sections of southern Mexico.

SOURCE OF SUPPLY OF "NAFTALAN."

The following particulars of the source of supply of the product known as "Naftalan," collated by the United States Consul at Constantinople, may be of interest to petroleum companies and chemical organisations:—

The Naftalan Oilfields, which produce this product, are situated in Transcaucasia due south of the railway which connects Tiflis and Baku, ten miles distant from the station of Gerhan. These fields have been closed down since 1917, or, rather, were abandoned by the engineers and operators owing to the military operations of the Soviet forces. There are apparently no present prospects of the fields being re-opened in the near future.

The Naftalan product is highly recommended in Russia by the medical profession for open wounds and skin diseases, and was so successfully used on the Russian front during the World War, that the Russian Government ordered the entire output put up in small tins for the use in the immediate treatment of fresh wounds. Another indication of the curative properties of this product, is the fact that the Naftalan Oilfields were visited annually by many Russians suffering from rheumatism, paralysis, and other diseases, for the purpose of bathing in the crude oil.

Before the war, an agent in Marseilles held a contract for the entire output of Naftalan at a reported price of five rubles gold (10*s.* 6*d.*) per pound, a small supply only being reserved for Russia. From Marseilles, most of the Naftalan found its way to Germany. There was such a great demand for this medical preparation that an extensive plant was being constructed when work was stopped owing to the Russian revolution in 1917.

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FRIDAY, JULY 6, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICE.

INDIAN SECTION.

A meeting of the Indian Section Committee was held on Monday, June 25th. Present :—Sir Charles S. Bayley, G.C.I.E., K.C.S.I. (Chairman of the Committee), in the Chair, Lord Askwith, K.C.B., K.C., D.C.L. (Chairman of the Council), Sir Charles H. Armstrong, Sir Thomas J. Bennett, C.I.E., M.P., Sir M. M. Bhownaggree, K.C.I.E., Sir Valentine Chirol, Mr. William Coldstream, B.A., I.C.S., retd., Sir Edward A. Gait, K.C.S.I., C.I.E., Ph.D., Sir Henry Ledgard, Major-General Beresford Lovett, C.B., C.S.I., Sir John O. Miller, K.C.S.I., Mr. N. C. Sen, O.B.E., Major H. Blake Taylor, C.B.E., Mr. N. N. Wadia, C.I.E., and Colonel Sir Charles E. Yate, Bt., C.S.I., C.M.G., M.P., with Mr. G. K. Menzies M.A. (Secretary of the Society) and Mr. S. Digby, C.I.E. (Secretary of the Indian and Dominions and Colonies Sections).

PROCEEDINGS OF THE SOCIETY.

ANNUAL GENERAL MEETING.

The One Hundred and Sixty-ninth Annual General Meeting for receiving the Report of the Council, and the Treasurers' Statement of Receipts and Payments during the past year, and also for the Election of Officers and New Fellows, was held in accordance with the By-laws on Wednesday, June 27th, at 4 p.m. The RIGHT HON. LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, in the Chair.

The Secretary read the notice convening the meeting, and the Minutes of the last Annual General Meeting held on June 28th, 1922.

The following candidates were proposed, balloted for, and duly elected Fellows of the Society :—

Abdoolabhoy, Mohomedally, Madras, India.
Allen, James Key, F.R.H.S., Chatham, Kent.
Anand, Hansraj, District Amritsar, India.
Boman-Behram, R. B., Bombay, India.
Branscombe, Charles W., London.
Buksh, P. Elahi, Calcutta, India.
Calico Printers, Federation of, Manchester (J. L. Edmondson, Secretary.)
Cochrane, John Williams, B.Com. London.
Daude, E. F. B., Idaho, U.S.A.
Derrick, E., London.
Edwards, Norman F., London.
Eshelby, Alan Wymar, Seattle, Washington, U.S.A.
Eyanson, Prof. Charles Louis, B.S., Hartford, Connecticut, U.S.A.
Good, Prof. John W., Ph.D., Georgia, U.S.A.
Gordon, Prof. Neil E., A.M., Ph.D., Maryland, U.S.A.
Gupta, Sudhansu Mohon, M.B., Assam, India.
Holbrook, Colonel Sir Arthur, K.B.E., M.P., London.
Jacob, Charles., St. Alban's, Herts.
Khan, K. Inayatullah, M.A., Peshawar, India.
Leach, Frank L., Tatanagar, India.
Mehta, K. L., Cawnpore, India.
Milne, John Alexander, C.B.E., London.
Munro, Harold Neville, A.I.E.E., London.
Narain, B. Kashi, Moradabad, U.P., India.
Narielwala, A. S., Bombay, India.
Paul, William Ross, Canada, U.S.A.
Richards, Stephen, London.
Ruane, Austin Anthony, Birmingham.
Searson, Prof. James W., Nebraska, U.S.A.
Sen, Dewan Bijoy Kumar, M.A., B.L., Bengal, India.
Sinha, Kumar Gangananda, M.A., Bihar, India.
Sinha, Rai Saheb Raghunath Pershad, Chapra, Saran District, India.
Smith, John D., London.
Underhill, Reginald Stanley, Nepal, India.
Walker, Hiram H., Ontario, Canada.
White, Joseph J., Mem.Am.Soc.M.E., New Jersey, U.S.A.

The CHAIRMAN appointed MAJOR H. BLAKE TAYLOR, C.B.E., and MR. ROBERT J. MONEY scrutineers, and declared the ballot open.

The SECRETARY then read the following—

REPORT OF COUNCIL.

I.—The Society's House.

A year ago the Council had the pleasure of reporting that they had secured the freehold of the Society's House. The next step was to renovate the interior of the building. This work was started as soon as possible after the close of the session in June, 1922, and was completed last January. An illustrated account of the renovations was published in the *Journal* of March 2nd, 1923. The changes have been very warmly approved by those visiting the House, and Fellows have begun to make use of the attractive Library and Reading Room, in which afternoon tea can be obtained.

The Council feel that the Society is to be congratulated on having raised £43,000 out of the £50,000 at which they aimed. This enabled them to purchase the freehold outright, without recourse to a mortgage, but practically nothing was left over for renovations, furnishing, etc. The cost of this is estimated at about £7,000—it has not yet been found possible to get in all the accounts—and, to meet this, a running overdraft has been arranged with the bankers. The Council are naturally anxious to reduce the amount as rapidly as possible, and they take this opportunity of appealing once more to the generosity of those Fellows who have not yet subscribed to the Building Fund.

II.—Ordinary Meetings.

Probably no one has a fuller knowledge than Lord Askwith of the misery caused to individuals and the havoc wrought upon industry by strikes and lock-outs: probably no one has done more than he to compose differences between employers and employed. A very special interest, therefore, attaches to his inaugural address on "The Value of Lock-Outs and Strikes," which opened the session. After referring to the principal industrial disputes in this country during the last century, and dealing in more detail with those of recent years in the most important of which he himself acted as arbitrator, he quoted some figures to show the appalling cost to the nation of employing this disastrous way of settling trade disputes. From 1893 to August, 1922, no fewer than 381,817,000 working days were lost. During three full years of the war, 1915-1917, 11,430,000 working days were lost; while during the three years 1919-1921 no fewer than 148,014,000 (or nearly 39 per cent.) working days were lost. At a time when every effort is necessary to repair the ravages of war, it is clear that the country cannot afford the frightful drain upon its strength which is indicated by these figures.

A paper on a closely related subject, "Industrial Arbitration," was read later on in the session by Sir William Mackenzie, President of the Industrial Court. He traced the history of the various attempts to compose differences between employers and employed from the year 1747, when Justices of the Peace were given jurisdiction in such disputes during the currency of a hiring. This historical portion of the paper is all the more valuable because it was hitherto impossible to find the facts concisely put together in any available form. A very handsome tribute is paid to the work of Lord Askwith as Chief Industrial Commissioner—a work which was none the less important because it ultimately paved the way for the establishment of the Industrial Court. Sir William described in considerable detail the methods of procedure of this body, and he expressed the opinion that with its establishment we are entering a new era in the settlement of industrial disputes.

It was considered appropriate that at the earliest possible opportunity after the opening of the Society's renovated house, an account should be given of its immediate surroundings. Accordingly a paper was read by Mr. John Slater, entitled, "The Strand and the Adelphi: their Early History and Development." He told the stories of Arundel, Essex and Somerset Houses, the Savoy Palace, and all the other great houses of the Strand. He also showed some most attractive lantern slides of the Angel Hotel and various smaller dwellings in the neighbourhood, which suggested that during the last four or five centuries the Strand has lost in picturesqueness as much as it has gained in sanitation and cleanliness. An excellent account was given of the Adelphi, and remarkable flashlight photographs were exhibited, showing the fine architectural features of the "Arches," which many have heard of but few have seen.

Beating is one of the most important processes in paper manufacture, and any improvement in the methods is likely to have most beneficial effects on the industry. Dr. Sigurd Smith (of Charlottenlund. Den-

mark), who has devoted a great deal of study to the theory and practice of beating, explained the exhaustive analysis he had made of the complex operations involved, and showed a general design of a beater contrived by him to realise, in an effective and economical manner, the potentialities of the factor which has been styled "beater bar fibrage." The description of Dr. Smith's work is too long and too technical to be attempted here, but his paper appeared to satisfy a critical audience of manufacturers that his researches would have an immediate and beneficial effect upon the whole process of paper making.

The damage done to person and to property by the contamination of the air through excessive smoke has been generally recognised for many years, but experts still differ as to the best means of minimising the nuisance. Bailie William B. Smith, in his paper, "The Economy of Smoke Abatement," emphasised the need for drastic action on financial grounds, and urged the greatly extended use of gas both for industrial and domestic purposes. In the discussion which followed the paper, pleas were put in for the use of solid smokeless fuels, and the coal fire was also defended on æsthetic and sanitary grounds.

The modern safe or strong room has to be of such a nature that it can resist the attacks of the scientific burglar, skilled in the use of liquid explosives and cutting flames. The safemaker, therefore, has to keep pitting his brain against clever and up-to-date adversaries, and as they devise new methods of attack so he must invent new methods to defeat them. The latest developments in these directions were described by Mr. Emory Chubb, who has devoted many years to the invention of burglar-proof devices.

In a paper entitled "The Hot Wire Microphone and its Applications to Problems of Sound," Major W. S. Tucker described a very delicate and beautiful contrivance, which, essentially a war invention, has been developed into an instrument not only for detecting but for measuring sound and vibratory motion. It was first designed to locate enemy guns, and it may be adjusted to select certain sounds and ignore others. Among the many practical uses to which it has already been put is the locating of fog horns in dense fogs, while for medical purposes it promises to prove very valuable: graphs can be obtained showing movements of the blood, the effects of different drugs, of mental agitation and so forth. It further appears probable that the instrument will be able to provide a scientific unit of sound, the lack of which has been one of the principal hindrances to the advance of the science of acoustics.

Sir Sidney Harmer's paper, "The Loss of Colour in objects exposed to Light," described a number of experiments conducted by himself to test the relative injuriousness of different kinds of illumination and the efficiency of tinted glasses. The author was led to believe that light alone was not the cause of fading, while Dr. Alexander Scott, who is in charge of investigations on somewhat similar lines, which are being conducted at the British Museum, is inclined to attribute the trouble to hydrogen peroxide. In view of the enormous value of the contents of our museums, it is most desirable that further experiments should be conducted with a view to preserving the objects as long as possible.

The sixth Trueman Wood Lecture was delivered by Professor Sir William H. Bragg on "New Methods of Crystal Analysis and their Bearing on Pure and Applied Science." Sir William Bragg has devised means for utilising X-rays in studying the formation of crystals, and has thus been able not only to verify or correct what was hitherto no more than speculation, but to carry certain knowledge far beyond previous theory. This branch of science is young, but it has already thrown light on the structure of materials, such as iron and steel, aluminium and kaolinite, and such knowledge is sure, sooner or later, to result in important industrial applications.

There seems to be little doubt that dust, due to the dry rubbing-down process, is the cause of much of the sickness suffered by painters. If the dust can be got rid of, the painter's trade should lose most of its dangers. Mr. C. A. Klein, who has for many years conducted ingenious and painstaking researches in connexion with this and other dangerous trades, in a paper entitled "Hygienic Methods of Painting," described the advantages of the damp rubbing down process. Although this is not new, it has been but little employed hitherto on account of certain technical difficulties; but the invention of a waterproof sandpaper has done much to overcome these difficulties. The process has

been approved as practicable by the National Federation of Master Painters of Great Britain, and they have authorised their representative at the International Labour Conference at Geneva to accept the process of damp rubbing down as a compulsory obligation in the use of white lead paints.

In their lecture, "The Relation between Chemical Constitution and Antiseptic Action in the Coal Tar Dyes," delivered under the Dr. Mann Trust, Mr. Thomas H. Fairbrother and Dr. Arnold Renshaw summarised the results of a series of experiments which they have been conducting during the past five years. The effects of some of the coal tar dyes on various protozoa and bacteria are very marked. For instance, in certain sewage tanks which were bulking very seriously, it was found that the addition of one part in 80,000 of a derivative of the Meldola blue class killed all the *paramœcia* in the tank almost instantaneously. In their work the authors of this paper aim at discovering bactericidal drugs which will kill the injurious object without affecting other things—in other words, drugs which shall be monotropic, or have an affinity for one germ only. Such substances would be invaluable not only in medicine, but in countless directions. Thus, the leading agricultural experts are of opinion that great improvements could be effected in agriculture if the soil could be freed from protozoa without harming the nitrifying bacteria.

Mr. Charles R. Darling, who had previously read two excellent papers and delivered two courses of Juvenile Lectures and two courses of Cantor Lectures before the Society, read another paper on "Electrical Resistance Furnaces and their Uses." Although the resistance furnace only started as a special laboratory appliance about twenty years ago, several kinds are now manufactured for such commerical purposes as the hardening and tempering of steel, the annealing of wire, the heating of rivets, etc. These are divided into two classes, metal-wound furnaces and carbon resistance furnaces. An interesting demonstration of their uses was given at the meeting, when Mr. Darling also showed an extraordinarily ingenious device, invented by himself and the Hon. C. W. Stopford, for giving an audible signal when demagnetisation of the article heated in the furnace is completed.

A subject somewhat akin to that discussed by Mr. Darling was dealt with in Mr. W. J. Rees's paper, "The Durability of Refractories." The importance of refractories can hardly be over-estimated. Their utilisation is at the basis of almost all industrial operations, and, as Mr. Rees remarked, "during the European War, the limiting factor in the production of munitions was the rate of production and application of refractory materials for the building and maintenance of furnaces for the metallurgical glass and ceramic industries." Very great progress has been made in the study of refractories during the last ten years, and much of the work has been done by Mr. Rees at the University of Sheffield; but as our knowledge of the subject grows, so does also the demand for materials which will stand higher and higher temperatures: for certain purposes materials are now required for work at temperatures of the order of 1800° C.

As Mr. C. Ainsworth Mitchell pointed out in his paper, "Handwriting and its Value as Evidence," the examination of handwriting has been regarded with considerable suspicion, being placed in the same sort of category as phrenology, graphology and palmistry. By means of photographic enlargement and careful measurement of angles and other characteristics, however, it seems that something like a scientific basis is being found for the study. Both Mr. Mitchell and several barristers who spoke in the discussion quoted interesting cases where the crucial evidence had been supplied by the experts in handwriting, and the opinion seemed to be generally held that their testimony is coming to bear more and more weight in courts of law.

To those having cognisance of forestry work the question of our future supplies of timber is causing grave anxiety. Owing largely to the ever-increasing demand for paper pulp, forests are disappearing at an alarming rate. The United States, once a great exporter of timber, can now hardly supply herself, and her demands are reaching the British Empire. Professor E. P. Stebbing, in his paper, "The Forests of North Russia and their Economic Importance," drew attention to those immense resources which are at present practically closed to us, although, just before the war, Russia had become the chief supplier of timber to the British markets. He urged that we should make a strenuous endeavour to secure a foothold in these regions before

they are monopolised by other nations, and he pleaded for the formation of a British syndicate to obtain from the Russian Government large concessions of forest land in Northern Russia. If we fail to do this, we shall, in his opinion, have to repeat the policy of the past, and buy our requirements from the foreigner who may obtain the concessions, merely adding his profits to the price we shall have to pay for our timber.

The history of Sarawak, owing to the romantic way in which it fell under the sway of the Brooke Rajahs in the early "forties," is known to many people, but comparatively few have any idea of the resources and trade of the country. These were the subject of a paper by Mr. Edward Parnell, who has spent many years in Sarawak, first as a member of the Government service and latterly as managing director of the Sarawak Steamship Company. The principal resources are pepper, gambier, sago, jelutong, various valuable hardwood timbers, and some minerals, such as antimony, quicksilver, gold, coal, etc. Probably, however, the most valuable asset of all is the oil-field, which is being rapidly developed. It is the second largest field in the British Empire, and will be of very great importance in providing fuel for our ships in the Far East.

A paper on "Modern Abattoir Practice and Methods of Slaughtering" was read by Mr. Hal Williams, in which he pleaded for the abolition of private slaughterhouses and improvement in the treatment of animals immediately before slaughter. Great progress has been made in this direction in Australia, especially at Sydney, which is the centre of a very large meat industry, and where it is of the utmost importance that animals should be killed under the best possible conditions: otherwise, if they are submitted to fear, excitement and exhaustion before being slaughtered, the meat will not stand the process of refrigeration and the long delay before it is brought to the table. Owing to the excellent arrangements in the Sydney abattoir the beasts apparently do not experience anything more than a mild curiosity in their novel surroundings, and they are deprived of consciousness before they realise that they are in any danger whatever.

The Nineteenth Ordinary Meeting was devoted to a conference on the milk question, when three short papers were read:—(1) Professor R. Stenhouse Williams, "The Arguments for Maintaining an Open Market for Fresh Milk;" (2) Professor J. Cecil Drummond, "Changes in the Digestibility and Nutritive Value of Milk induced by Heating;" (3) Dr. S. S. Zilva, "The Effect of Heat on some Physiological Principles in Milk." A demonstration of some of the Chemical Changes in Milk on Heating to various Temperatures was also given by Captain John Golding. The principal question under discussion was whether it is advisable to continue the Pasteurisation of milk for ordinary purposes, or whether the aim should not rather be to secure supplies of perfectly clean and wholesome milk that can be safely drunk without preliminary treatment. There seems to be but little doubt that pasteurisation destroys some of the most valuable and nutritive qualities of milk. On the other hand much of the milk that is at present supplied is unfit to drink unless it is pasteurised. Professor Stenhouse Williams showed that in Reading it has been found possible to provide on a commercial scale milk that is absolutely clean and healthy, and he urged that this is the ideal to set before farmers and dairymen.

The subject of "Flameless Incandescent Surface Combustion" was dealt with by Professor Bone in a course of Howard Lectures delivered before the Society nine years ago. The process developed by him and the late Mr. Cyril Douglas McCourt had then reached a certain stage where it showed great promise, especially in connexion with cooking apparatus; but difficulty was experienced in finding a suitable diaphragm, as with those then in use there was considerable danger of back firing. The war put a stop to further investigations for a time, but recently the problem of the diaphragm has been studied by Mr. F. J. Cox, and the demonstration given by him after the paper which Professor Bone read at the Twentieth Ordinary Meeting showed that great progress had been made towards a satisfactory solution. Already cooking apparatus using this system has been installed in several great restaurants, and it seems likely that developments may also be expected in connexion with steam raising in boilers and for other purposes.

Dr. F. W. Edridge-Green, who had previously read before the Society two papers on Colour Blindness, read a third on "Some Curious Phenomena of Vision

and their practical Importance." He discussed the somewhat thorny problem of how we see, and the parts played respectively by the rods, the cones and the visual purple; how after-images are produced, and why they vary according to the duration of the stimulus. The paper was followed by an interesting discussion in which an explanation was offered of the appearance of the so-called "hypnotic fluid," which is not likely to commend itself to the convinced believer in hypnotism.

A paper on "Industrial Lighting and the Prevention of Accidents" was read by Mr. Leon Gaster, who is generally recognised as a staunch advocate of adequate lighting in factories, and whose work as the founder and Hon. Secretary of the Illuminating Engineering Society has done much to encourage the Home Office to turn their attention to securing satisfactory conditions in this regard. He had previously given several lectures and papers before the Society, dealing with various aspects of illumination. On this occasion he considered defective lighting as a cause of accidents, quoting figures to show that the frequency of accidents is greater in the dark winter months; he further demonstrated that it is a cause of industrial fatigue, and, as a corollary, of reduced production. As the cost of lighting is a comparatively small item in the expenses of running a factory, a very slightly increased percentage in output does a great deal more than cover the increased cost of improved illumination.

At the last Ordinary Meeting of the session, Mr. Samuel J. Sewell read a paper on "The History of Children's and Invalids' Carriages." Although there is a certain amount of evidence that a child's carriage was not unknown in Athens several centuries before the Christian era, and that it had appeared in China in the fourteenth century, the perambulator is a really quite modern development and nearly all the improvements in it have been designed by British manufacturers. Mr. Sewell was at great pains to examine the many patents which have been taken out in connexion with the trade, and to give due credit to those who have assisted in the evolution of the present-day perambulator.

III.—Indian and Dominions and Colonies Sections.

The Indian Section held seven meetings, the Dominions and Colonies Section three, and, following the plan adopted for the first time in the session of 1919-20, there were two joint meetings of the Sections.

The papers read and discussed in the Indian Section were:—"The Development of Water Power in India," by Mr. J. W. Meares, C.I.E.; "The Settlements of Criminal Tribes in India," by Commissioner Booth Tucker; "A Clash of Ideals as a Source of Indian Unrest," by the Earl of Ronaldshay; "The Indian Census of 1921," by Mr. J. T. Marten; "Postal and Telegraph Work in India," by Mr. Geoffrey Rothe Clarke, C.S.I., I.C.S., and "The Participation of India and Burma in the British Empire Exhibition, 1924," by Mr. Austin Kendall. The annual Sir George Birdwood Memorial Lecture was delivered by Sir John H. Marshall, C.I.E., the title being "The Influence of Race on Early Indian Art."

In the Dominions and Colonies Section the papers read were:—"British North Borneo," by Major Owen Rutter; "The Dominion and Colonial Sections of the British Empire Exhibition, 1924," by Major E. A. Belcher, C.B.E., and "The Economic Conference and the Colonies," by Sir Edward Davson. The papers read at the joint meetings were:—"Recent Advances Towards the Solution of the Leprosy Problem," by Lieut.-Col. Sir Leonard Rogers, F.R.S., and "A Review of the Base Metal Industry, with Special Reference to the Resources of the British Empire," by Sir Richard A. S. Redmayne, K.C.B.

Mr. Meares described himself as practically in the position of delivering a funeral oration, for the Hydro-Electric Survey had become moribund, and he could not see any likelihood of its resurrection. Nevertheless, it had, he said, left some useful material behind it, and the development of power already located must be looked to rather than further search for new sites. He estimates that at least seven million e.h.p. is "in sight," but he does not in present circumstances expect industrial expansion on a scale to require more than a small fraction of the power now running to waste. "Talk as we will, there are," he said, "no great signs of the industrial era coming in. The one thing that may help it along is really cheap power." And he would like to see business men attempting to provide it "unhampered by taxation."

One of the minor but not insignificant problems of the British Raj is the control and reformation of the considerable tribes

of hereditary criminals to be found all over India. In the Punjab alone, the number of these people, men, women and children, is estimated at 130,000; in the United Provinces the total is even larger. It was in the latter Provinces that the admirable work which has been carried on for the past fourteen or fifteen years by the Salvation Army, was started by Commissioner Booth Tucker, who abandoned a promising career as an Indian "Civilian" to accept service in the great organisation with which his name is so honourably associated. Of the settlements he described in his paper dealing with a population approaching 8,000, eight are in the United Provinces, five in the Madras Presidency, three in the Punjab, one in Bihar and Orissa, and one in the Bengal Presidency. Taking part in the discussion, Sir John Prescott Hewett, M.P., ex-Lieutenant Governor of the United Provinces, at whose request the Salvation Army embarked on this "wonderful experiment," declared that it bids fair to have more effect in the reduction of crime in India than such dramatic efforts as have been made to suppress *thuggi*, or than the ordinary police administration.

The thesis of Lord Ronaldshay's fine paper, which has attracted marked attention both here and in India, was that the causes of unrest are more fundamental than economic and political dislocation produced by the War or the Turkish imbroglio. In short, the source of unrest which seems to him to be one of fundamental importance, is, in his words, "the heat generated by the clash of two conflicting ideals, the offspring of two different outlooks upon the universe, those of the East and the West respectively." Examining the present position in India from this standpoint, he arrived at the conclusion that such unrest is healthy, and should command our sympathy and respect. "It becomes a danger and a menace to India herself when it excites men to extremes causing a loss of all perspective." Is there not for Indians, he asked, a golden mean between the adoption *in toto* of everything of the West on the one hand, and an equally rigorous rejection of all that the West has to offer on the other? The speeches of the Chairman (Viscount Peel), Sir Valentine Chirol and others who joined in the discussion, were on the same high level as Lord Ronaldshay's eloquent discourse.

Owing to the succession of valuable papers contributed by previous Indian Census Commissioners, the Society has long been familiar with the general method by which the enumeration of the people of that Empire is carried out. In the introduction to his paper, Mr. Marten, therefore, confined himself to a brief recapitulation of the main points of the excellent Indian system of enumeration and tabulation. He then gave an account of the special difficulties and obstacles encountered; an idea of the lines on which he and his colleagues directed the census of 1921, and an estimate of the accuracy and value of the information they obtained. One of the influences affecting the life of the people during the decade under review, was the terrible influenza epidemic which, starting in the latter part of 1918, prevailed in almost every portion of the country, and wiped out in a few months practically the whole natural increase in the population for the previous seven years. The total mortality caused by the outbreak, and covering a period of only four or five months, amounted, according to a conservative estimate, to 12½ millions.

Until ten years ago, postal and telegraph work in India was performed by two distinct departments; the origin and development of each were explained by Mr. Geoffrey Clarke before he came to the *pièce de résistance* of his singularly able paper, the problems which face the united departments at the present day. Incidentally, he referred to the much-discussed question of the Indian Imperial Wireless Station. The Indian Government, he explained, have always been most anxious to obtain direct wireless communication with Great Britain, and to form part of a great imperial wireless chain. They are, however, not in a position to incur the heavy outlay involved, and have decided to leave the task to private enterprise. With reference to the suggestion made from time to time to carry the mails by air, he said that nothing like a reasonable proposal, or a firm offer, had, up to the date of his paper (April 6th), been made to the Government of India. As to air services in India, he expressed the opinion that these can be successfully established when a really good commercial aeroplane, economical in the use of petrol, has been designed for use in India. In a letter regretting that a public engagement prevented him from attending the meeting, Sir William Brancker stated that if India had a dozen more men of the

same calibre as Mr. Geoffrey Clarke, air transport would become a flourishing means of communication in the Indian Empire before five years were out.

Mr. Kendall reminded us that India has for a very long time been noted for certain classes of products as well as for art work and craftsmanship that are peculiarly her own. In deciding to participate in the Empire Exhibition of 1924, she wishes to demonstrate that in respect of the greater industries she is progressing rapidly to a place among the leading nations of the world. "She has secured recognition from the Council of the League of Nations as one of the eight chief Industrial States of the world, and, in representation at the Exhibition, she looks for an opportunity of proving her status." Although the invitation to her to take part in the Exhibition came at a time of acute financial stringency, and when, under the new constitution, her various provinces had been entrusted with a much greater measure of independence in regard to expenditure of public funds than they ever enjoyed before, the response has been most gratifying. The Central Government have sanctioned an outlay of about £200,000, while the Provincial Legislatures have voted additional sums amounting in the aggregate to £125,000. That, in the circumstances, such substantial support should have been given, and given unconditionally, is regarded by Mr. Kendall as affording an "earnest of the definite intention of the Reformed Government that India's display shall form a working part of a British Empire Exhibition." Sir Henry McMahon, speaking in the discussion, mentioned that four out of the five members of the Standing Administrative Council of the Exhibition, viz., Lieut.-General Sir Travers Clarke, Sir James Allen, Sir Charles McLeod (who presided over the meeting) and himself, were present. He added that the Royal Society of Arts was proverbially quick at "spotting" a good thing, and that was why it was taking so much interest in the British Empire Exhibition. The paper just read was the second of the kind that had been given, and the aid the Society was lending was highly appreciated.

Sir John Marshall's brilliant discourse was in a measure complementary to the Sir George Birdwood Memorial Lecture delivered last year by Sir Thomas Arnold. The last-named dealt with Indian painting in its relation to Moslem culture. Sir John Marshall chose as his subject Indian Art in the pre-Moslem period, and analysed the factors that contributed to its genesis and subsequent evolution. Many writers on Indian Art have given to the Indo-Aryans the credit for all that is best in Indian culture, including the fine arts. Sir John Marshall, on the other hand, set himself the task of proving that, although the Vedic immigration did so much to develop culture generally, India is indebted to the earlier Dravidian or other pre-Aryan people for its "natural and inborn love of ornamental design." Lord Curzon of Kedleston, who presided over a crowded and appreciative audience, paid an eloquent tribute to the achievements of Sir John Marshall as Director-General of the Archæological Department in India, since the formation of that department by his Lordship some twenty years ago. This is the seventh time that Lord Curzon has honoured the Society by taking the chair at a meeting of the Indian Section; the fact that these occasions were spread over a long term of years beginning in 1894 indicates, as he observed, his continuous interest in what he termed "that glorious country."

In the charming description of British North Borneo, by Major Rutter, the story of whose acquisition by the British reads, as he said, like a page taken from romance, the present position was contrasted with the former state of things. Fifty years ago pirates infested the whole length of the coasts; communities of head hunters raided the hill districts, and there was no semblance of organised government. To-day, there are no pirates, and the descendants of the head-hunters are employed in useful occupations. Although much has been done to develop the principal natural resources of the country—agriculture, forests and minerals—progress is slow, and, as in other distant parts of the Empire, one of the pressing needs is increased population. So far, not more than one per cent. of the vast expanse of territory has been opened up.

Major Belcher, in his extremely interesting paper, emphasised an aspect of the coming Empire Exhibition, which, he submitted, needs to be kept in mind. The Exhibition will be a great publicity campaign, in which there are three partners: first the Dominions and Colonies; secondly

the organisers of the Exhibition, and, lastly, the British public. Sentiment has counted for a good deal, but something more was required to "induce a Dominion to pull a quarter of a million sterling out of its pocket and to spend it on the construction and equipment of a building 12,000 miles away." The Exhibition authorities must do their part, but it is equally the duty of the public at home to give a fair run to the Dominions and Colonies, "because the amount of Empire produce which can be consumed within the Exhibition is negligible compared with what might be consumed outside." In other words, the British consumer must support the "family shop."

Sir Edward Davson's important paper dealt with urgent economic problems affecting the Colonies as distinguished from the Dominions. He suggested that for the purposes of the Imperial Conference shortly to assemble in the capital of the Empire, in order to consider the best means of developing Empire trade, the Colonies should be divided into four main groups, namely, East Africa, West Africa, the Far East and the Atlantic, and that a representative of each should attend the Conference in an advisory capacity. He indicated some of the questions that he hopes the Conference will consider. His aim, he remarked, was to suggest that the time has come for the evolution of an Imperial system, and for yet further development, coupled, where possible, with economies in administration in order to secure the welfare and prosperity of our world-encircling girdle of Colonies and Protectorates.

One striking section of Sir Leonard Rogers's remarkable paper on Leprosy was that in which he referred to the investigations so laboriously carried on in recent years by himself and other devoted research workers. He was able to say that, although it is still too early to claim permanent cure of, perhaps, the greatest calamity that affects mankind, a few typical cases treated by him have now remained free from all signs of the disease for at least five years, while in other cases infectivity is greatly reduced, or has been completely removed. Moreover, in several widely separated endemic areas, early cases previously hidden are coming forward in large numbers, and the sufferers are asking for treatment, a very encouraging sign. Sir Leonard also made the reassuring statement that there is little danger of leprosy spreading in this country. In the temperate zone, given good sanitary conditions, the disease does not tend to increase. One authoritative speaker expressed his belief that the problem of leprosy in the British Empire would be fought out and solved in India. Earl Winterton, M.P., Under Secretary of State for India, who occupied the chair, said he was pleased to see that the Society had recently redecorated its premises, and he congratulated it on the result. The pleasure it had been to him to preside on that occasion was greatly enhanced by the beautiful room in which they were assembled, one of the most beautiful of the kind he had ever seen.

In his admirable and comprehensive survey of the base metal industry, Sir Richard Redmayne confined himself to copper, lead, zinc, tin and aluminium. "It is," he said, "a somewhat startling fact that the supply of certain of the base metals will be exhausted long before either coal or iron cease to be produced." In the course of the discussion, Lord Morris, a Member of the Imperial Mineral Resources Bureau, of which Sir Richard Redmayne is the distinguished Chairman-Governor, expressed the hope that the Society would not allow the occasion to rest with the reading of the paper, and with the speeches it had evoked, but take special steps to have the facts adduced brought home to the authorities concerned.

IV.—Cantor Lectures.

In the first course of Cantor Lectures Professor W. A. Bone dealt with "Brown Coal and Lignites," describing their origin and classification, their geographical distribution, their physical texture and chemical composition. He then discussed the question of their commercial utilisation, methods of drying and briquetting them, and concluded with an account of their carbonisation and their employment as steam-raising fuels. In the course of his lectures he drew special attention to the great Morwell deposits of brown coal in Victoria: these are of extraordinary thickness—without parallel elsewhere in the world—and their economic importance to the British Empire can hardly be over-estimated.

The second course was devoted to "The Vulcanisation of Rubber," by Dr. Henry P. Stevens. The methods of vulcanisation were described, the various vulcanising

agents, cold cures, accelerators and the vulcanisation of rubber sols and gels. In the last lecture Dr. Stevens dealt with the measurement of vulcanising effort, and the theories of vulcanisation.

The very difficult subject of "Accurate Length Measurement" was treated by Mr. J. E. Sears in the third course. He described and exhibited instruments for measuring to within a millionth of an inch, and he also dealt with the question of measuring gauges and gears. The importance of great precision in gauge measurement was clearly demonstrated during the war, when—to take one instance only—the production of shells depended on the number of accurate gauges that were available.

The demand for nitrates, whether for purposes of peace or war, continues to grow: they are necessary alike for fertilisers, dyestuffs, and explosives. There are now three principal processes of manufacturing them from the air: the electric arc, the calcium cyanamid, and the synthetic ammonia processes. All these were discussed by Mr. E. Kilburn Scott in his course "Nitrates from Air." He described the chief plants now in operation in different parts of the world; he urged the necessity of seeing that the British Empire should develop its potential resources in this connexion, and concluded with a strong plea for the encouragement of scientific research in various branches of the industry.

V.—Howard Lectures.

In 1909 Professor Gerald Storey gave a course of Cantor Lectures on Steam Turbines. Since that date there have been many important developments in the turbine, and immense increase in its popularity. Mr. Stanley S. Cook (of the Parsons Marine Steam Turbine Company) gave an excellent account of these in a course of Howard Lectures, in which he dealt more particularly with the principles of compounding, the introduction of mechanical gearing for marine and land turbines, and the latest improvements in their economical working by re-heating and cascade feed-heating. This course, together with the earlier lectures of Professor Storey, gives a very complete history of the turbine from the time of its invention by Sir Charles Parsons to the present day.

VI.—Dr. Mann Juvenile Lectures.

The second course of Juvenile Lectures under the Dr. Mann Trust was delivered by Mr. Charles R. Darling, his subject being "The Spectrum, its Colours, Lines and Invisible Parts, and some of its Industrial Applications." The first lecture was devoted to the visible parts of the spectrum, and was illustrated by some very beautiful experiments; the second dealt more particularly with the invisible portion, and here Mr. Darling disclosed some information which is not generally known. One of the most remarkable accomplishments during the war was the transportation of all the American troops across the Atlantic without the loss of a single ship by submarines. The ships were able to keep together throughout the darkest night by means of an invention of Professor R. W. Wood, of Baltimore. He had discovered a glass which was opaque to ordinary light, but allowed the ultra-violet rays to pass through quite easily. These rays, issuing from a convoying ship, fell on the specially prepared screens with which every vessel was fitted, and they were thus enabled to keep in touch with each other, although not a single ray of visible light appeared to tell the enemy of their whereabouts.

VII.—Albert Medal.

The Albert Medal of the Society for the current year has been awarded in duplicate by the Council, with the approval of the President, H.R.H. the Duke of Connaught, to Major-General Sir David Bruce, K.C.B., D.Sc., LL.D., F.R.C.P., F.R.S., and to Colonel Sir Ronald Ross, K.C.B., K.C.M.G., D.Sc., LL.D., M.D., F.R.C.S., F.R.S., "in recognition of the eminent services they have rendered to the Economic Development of the World by their achievement in Biological Research and the Study of Tropical Diseases."

VIII.—Medals for Papers.

Eight medals have been awarded for the papers read before the Society during the current session—four for papers read at the Ordinary Meetings, two for those read in the Indian Section, and two for those read at Joint Meetings of the Indian and Dominions and Colonies Sections.

The awards are as follows:—

Papers read at the Ordinary Meetings:—

Overingenieur Dr. Sigurd Smith (Charlottenlund, Denmark), "The Action of the Beater in Paper Making, with special reference to the Theory of the Fibrage and

its application to Old and New Problems of Beater Design."

Major W. S. Tucker, R.E., D.Sc., "The Hot Wire Microphone and its Applications to Problems of Sound."

Edward Percy Stebbing, M.A., F.L.S., Professor of Forestry, University of Edinburgh, "The Forests of North Russia and their Economic Importance."

Sir William Mackenzie, K.B.E., K.C., "Industrial Arbitration."

Papers read in the Indian Section :—

The Earl of Ronaldshay, G.C.I.E. late Governor of Bengal, "A Clash of Ideals as a Source of Indian Unrest."

Geoffrey Rothe Clarke, C.S.I., O.B.E., I.C.S., Director-General, Posts and Telegraphs, India, "Postal and Telegraph Work in India."

Papers read at Joint Meetings of the Indian and Dominions and Colonies Sections :—

Lieut.-Colonel Sir Leonard Rogers, C.I.E., F.R.S., F.R.C.P., F.R.C.S., Physician and Lecturer, London School of Tropical Medicine, "Recent Advances towards the Solution of the Leprosy Problem."

Sir Richard A. S. Redmayne, K.C.B., M.Sc., M.Inst.C.E., M.I.M.E., F.G.S., "A Review of the Base Metal Industry, with Special Reference to the Resources of the British Empire."

For many years it has been the practice that no medals should be awarded to members of the Council, or to readers of papers who have previously received medals from the Society. Acting on this rule the Council were precluded from considering the following papers :—

John Slater, F.R.I.B.A., "The Strand and the Adelphi: their Early History and Development."

Charles R. Darling, F.Inst.P., A.R.C.Sc.I., "Electrical Resistance Furnaces and their Uses."

William Arthur Bone, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology, South Kensington, "Surface Combustion—with Special Reference to Recent Developments in Radiophragm Heating."

Leon Gaster, "Industrial Lighting and the Prevention of Accidents."

Sir Edward Davson, "The Economic Conference and the Colonies."

The Council desire, however, to express their high appreciation of these papers.

IX.—Swiney Prize.

The next award of the Swiney prize will be made in January, 1924, the eightieth anniversary of the testator's death. Dr. Swiney died in 1844, and in his will he left the sum of £5,000 Consols to the Society of Arts, for the purpose of presenting a prize on every fifth anniversary of the testator's death, to the author of the best published work on Jurisprudence. The prize is a cup, value £100, and money to the same amount; the award is made jointly by the Royal Society of Arts and the Royal College of Physicians.

In accordance with the arrangement with the Royal College of Physicians, the award next year will be for General Jurisprudence.

Any person desiring to submit a work in competition, or to recommend any work for the consideration of the judges, should do so by letter addressed to the Secretary of the Society, not later than November 30th, 1923.

X.—Owen Jones Prizes.

With the kind assistance of the Director of the Victoria and Albert Museum, the Council again in 1922 arranged for a competition of students from Schools of Art in accordance with the terms of the Owen Jones Trust.

The subjects of competition were :—

Architectural Decoration : Including Stained Glass, Mosaic for Walls and Floors, Plasterwork in relief and incised, Inlaid Marble and Stones, Lettering for Memorials.

Woodwork and Cabinet Work : Including Carving in Wood, Ivory and Bone, Inlay, Chairs, Chests, Cabinets.

Textiles : Including Tapestries, Carpets and Rugs, Moquettes, Floor-coverings (*e.g.*, Linoleums and Floorcloths).

One hundred-and-thirty-four designs were submitted by 118 competitors from 29 schools.

Unfortunately, the advance in the standard of excellence, which was apparent in the competition of 1921, was not maintained, and the Judges only recommended the award of five out of the six prizes offered. The special Mulready Prize of £20 was given to Miss C. Honor A. Howard-Mercer, of the L.C.C. School of Arts and Crafts, Hammersmith, for a design for a mosaic, with full-size detail.

The work was exhibited to the public at the Victoria and Albert Museum from July 29th to September 17th.

XI.—Annual Competition of Industrial Designs.

About a year ago the Council decided that, having regard to the success which had attended the somewhat limited competition for the Owen Jones Prizes, the time had come when it would be opportune to launch a more extensive organisation for the encouragement of artistic design, in which the Owen Jones Competition should be incorporated. At the suggestion of Sir Frank Warner and Mr. Carmichael Thomas a small Committee was appointed which went carefully into the matter.

It is proposed to hold an annual competition of Industrial Designs (*a*) limited to students of schools of arts, and (*b*) open to any competitors. The awards will take the form of Diplomas, Medals, Money Prizes, and, if funds permit, of Scholarships. A very high standard will be maintained in awarding the Diplomas, which will only be given to competitors of outstanding ability and originality. It is hoped that the possession of the Diploma will shortly come to be recognised as the hall mark of an exceptionally brilliant designer, and that it will be the means of securing for him employment on the most favourable terms by bringing his work to the notice of those manufacturers who are looking out for designers of the first class.

Very strong Committees have now been formed to deal with Architectural Decoration, Textiles, Furniture, and Book Production. The Chairmen of these Committees are respectively Sir Charles Allom, Sir Frank Warner, K.B.E., Mr. Harold Waring, C.B.E., and Mr. J. A. Milne, C.B.E. Subjects for the first competition, to be held in 1924, have been carefully considered and will be ready for publication shortly.

The Committees are all of opinion that interest in the competition will be greatly stimulated if they can offer substantial money prizes, and in particular they would like to be able to offer a travelling scholarship to a candidate who reaches a very high level of excellence. They believe that this would be invaluable in giving a brilliant young designer full opportunities and leisure for developing his talents, and they feel that the influence of even a small number of such artists would soon make itself felt throughout all departments of British industries into which artistic design may be said to enter. They, therefore, appeal earnestly to the public spirit and munificence of manufacturers and others who have the welfare of our artistic industries at heart.

XII.—Examinations.

The Examinations continue to grow in a most satisfactory manner, the number of entries for this year again constituting a record. For the March series the figure was 22,363, as against 22,160 in 1922; for the May series the figure was 45,888, as against 38,171 last year; the totals for the two years being 68,241 and 60,331.

In order to show their growth the figures are given for the last five years, for 1914, which was then the record year, and also for 1916, which shows the effect of the war on the entries :—

Year.	Number of entries.
1914	37,974
1916	25,968
1919	34,173
1920	54,010
1921	55,182
1922	60,331
1923	68,241

The examinations are held in most of the principal cities and towns of Great Britain and Ireland, and in nearly all cases are conducted and supervised by the Local Education Authorities, to whom the Society is greatly indebted for the efficient manner in which these duties are carried out.

There were 335 Centres for the March Examinations, and 375 Centres for those in May. The County of London, where the Examinations are under the control and supervision of the London County Council Education Committee, is only reckoned as one Centre, though under this head are included entries from a very large number of Evening Institutes, Polytechnics, Proprietary Schools, etc. The number of entries for the County of London was 1,981 in March, and 14,676 in May.

The liberality of the Worshipful Company of Clothworkers has enabled the Council, as in past years, to offer the usual silver and bronze medals. These medals are very highly valued by the successful candidates, and they contribute not a little to maintain the high standard of the examinations.

The results of the First Division of the Examinations, held in March, have already been communicated to the candidates;

and those of the May Division will be announced as soon as possible.

A report giving full details of the year's Examinations will be published in the *Journal*, as usual, at a later date.

XIII.—Oral Examinations in Modern Languages.

The Oral Examinations are still in progress in various parts of the country. Particulars will be given in the annual report on the Examinations.

XIV.—New Council.

The Vice-Presidents retiring under the ordinary regulations are: Sir George T. Beilby, Sir Thomas J. Bennett, Lord Blyth (who is nominated as a Treasurer in place of Sir William H. Davison), and Sir Francis Grant Ogilvie. In their places the Council recommend Lord Curzon of Kedleston, the Earl of Durham, Lieut.-Colonel Sir Arthur H. McMahon, and Sir Alfred Yarrow.

The four Ordinary Members of Council retiring are: Sir Dugald Clerk, Professor John Bretland Farmer, Mr. John Somerville Highfield, and Sir Alfred Yarrow (who is nominated a Vice-President). In their places the Council recommend Mr. A. Chaston Chapman, Sir William H. Davison, Sir Edward Davson, and Rear-Admiral James de Courcy Hamilton.

Mr. John Slater is recommended as Soane Trustee in place of Mr. Alan S. Cole.

XV.—Obituary.

The Council have to regret the death of a number of distinguished Fellows who have died within the year.

The list includes two of the Society's Albert Medallists: Dr. Alexander Graham Bell, who in 1902 received the medal for his invention of the telephone; and Sir James Dewar, who in 1907 received it for his investigations into the liquefaction of gases and the properties of matter at low temperatures.

Lord Sanderson was for many years a member of the Council and served as Chairman from 1911-13.

Viscount Northcliffe was a Vice-President of the Society from 1916-19, and was re-elected in 1921, remaining in office until his death.

The Hon. Richard Clere Parsons was a member of the Council, with one or two short intervals, for twenty-one years. He took a deep interest in the work of the Society and frequently attended the meetings.

Sir Richard Vassar-Smith served for twelve months as a member of the Council.

Sir Charles Santley, the famous singer, had been a member of the Society for forty-seven years.

Sir William Meyer was a member of the Indian Section Committee.

Among other notable Fellows who have died during the last twelve months may be mentioned Mr. A. E. Carey, Sir Nayaran Ganesh Chandavarkar, Dr. Henry Clews, the Hon. Sir John P. Pringle, Mr. Arthur H. Reid, Mr. Alexander Ross, Mr. Arthur T. Walmisley, and Sir Joseph Walton.

XVI.—Société d'Encouragement Pour l'Industrie Nationale.

The Société d'Encouragement pour l'Industrie Nationale celebrated the 122nd anniversary of its Foundation from 7th-10th June. At the request of the Council Mr. C. F. Cross undertook to represent the Society on the occasion. An address of congratulation, signed by H.R.H. the Duke of Connaught, President of the Society, and Lord Askwith, Chairman of the Council, was presented.

Mr. Cross reported that he received a very warm welcome from the Société d'Encouragement. He was informed that the Société was modelled to a very large extent on the lines of the Royal Society of Arts, which they regarded almost as their parent. He suggests that there may be an opportunity of creating a definite link between the two Societies.

XVII.—Finance.

At the close of the last Annual Report the hope was expressed that the Income and Expenditure Account for 1922 would show a more satisfactory result than that for 1921. Happily this hope has been realised. The year 1921 resulted in an excess of expenditure over income of £405 15*s*. From the Financial Statement published in the *Journal* of June 22nd, it will be seen that in 1922 this deficit has been turned into an excess of income over expenditure amounting to £596 17*s*. 4*d*.

This satisfactory result is mainly due to the following causes: the cost of the *Journal* has fallen from £4,030 13*s*. to £3,343 16*s*. 2*d*.; and rent, rates and taxes from £1,065 4*s*. 11*d*. to £544 3*s*. 4*d*. On the other hand, the annual subscriptions of Fellows have dropped from £7,005 in 1921 to £6,448 17*s*., while the cost of salaries,

due in part to the growing amount of work in connexion with the Examinations, has increased from £3,336 to £3,706.

The fall in the amount of annual subscriptions is no doubt to be attributed to the continued depression in the state of trade, which renders people very chary of undertaking fresh responsibilities. The Council, therefore, urge upon Fellows the desirability of doing what they can to secure support for the Society amongst their friends.

Very considerable economies are being effected in connexion with the miscellaneous printing of the Society, especially in the printing of the Examination working papers; some relief from the very heavy expenses of postage will also be obtained under the latest postal regulations; and the Council hope that the Financial Statement for 1923 may prove still more satisfactory than that which has just been placed before the Fellows.

THE CHAIRMAN (The Right. Hon. Lord Askwith, K.C.B., K.C., D.C.L.) moved the adoption of the report, which was uanimously agreed to.

THE CHAIRMAN then proposed a cordial vote of thanks to Mr. G. K. Menzies (the Secretary), Mr. S. Digby (the Secretary of the Indian and Dominions and Colonies Sections), Mr. George Davenport (the Chief Clerk), Mr. J. H. Buchanan (the Accountant and Examinations Officer) and to the other officers of the Society for their services during the year. The Society, he said, was greatly indebted to Mr. Menzies and Mr. Digby for their efforts in obtaining the valuable papers and lectures given this Session, and he felt sure the members would endorse with acclamation a vote of thanks to the officers of the Society.

THE SECRETARY returned thanks for this expression of confidence in himself and in the other officers of the Society.

MR. ALAN A. CAMPBELL SWINTON, F.R.S., proposed a very hearty vote of thanks to Lord Askwith for all the time and attention which he had bestowed upon the affairs of the Society during the past session. He was sure they would all agree with him that they could not have had a more efficient Chairman of Council.

THE RIGHT HON. LORD BEARSTED said he had much pleasure in seconding the vote of thanks to the Chairman and cordially agreed with Mr. Campbell Swinton's remarks.

The CHAIRMAN acknowledged the vote of thanks, and asked that he might be allowed to retire to attend another meeting.

The ballot having remained open for half-an-hour, and the Scrutineers having reported, Mr. Carmichael Thomas, who succeeded Lord Askwith in the Chair, declared that the following had been elected to fill the several offices. (The names in italics are those of Fellows who have not, during the past year, filled the office to which they have been elected.)

PRESIDENT.

H.R.H. The Duke of Connaught and Strathearn, K.G.

VICE-PRESIDENTS.

Lord Askwith, K.C.B., K.C., D.C.L.
Sir Charles Stuart Bayley, G.C.I.E., K.C.S.I.
Lord Bearsted.
Marquess Curzon of Kedleston, K.G., G.C.S.I., G.C.I.E.
Edward Dent, M.A.
Earl of Durham, K.G., P.C., G.C.V.O
Peter MacIntyre Evans, M.A., LL.D.
Field-Marshal Earl Haig, K.T., O.M., G.C.B., G.C.V.O., K.C.I.E.
Lord Inchcape, G.C.M.G., K.C.S.I., K.C.I.E.
Sir Herbert Jackson, K.B.E., F.R.S.
Lt.-Col. Sir A. Henry MacMahon, G.C.M.G., G.C.V.O., K.C.I.E., C.S.I.
Senator Guglielmo Marconi, G.C.V.O., LL.D., D.Sc.
Lord Montagu of Beaulieu, K.C.I.E., C.S.I.
Hon. Sir Charles Algernon Parsons, K.C.B., LL.D., D.Sc., F.R.S.
John Slater, F.R.I.B.A.
James Swinburne, F.R.S.
Alan A. Campbell Swinton, F.R.S.
Carmichael Thomas.
J. Augustus Voelcker, M.A., Ph.D.
Sir Philip Watts, K.C.B., LL.D., F.R.S.
Sir Aston Webb, K.C.V.O., C.B., P.R.A.
Sir Henry Trueman Wood, M.A.
Sir Alfred Yarrow, Bt., M.Inst.C.E.

ORDINARY MEMBERS OF COUNCIL.

A. Chaston Chapman, F.R.S.
Charles Frederick Cross, F.R.S.
Sir William Henry Davison, K.B.E., D.L., M.P.
Sir Edward Dawson.
Sir Robert Abbott Hadfield, Bt., D.Sc., F.R.S.
Rear-Admiral James de Courcy Hamilton, M.V.O.
Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S.
Major Sir Humphrey Leggett, D.S.O., R.E.
Sir Philip Magnus, Bt.
Ernest H. Pooley, M.A., LL.B.
Sir George Sutton, Bt.
Sir Frank Warner, K.B.E.

TREASURERS.

Lord Blyth.
William Henry Maw, LL.D., M.Inst.C.E.

SECRETARY.

George Kenneth Menzies, M.A.

SOANE TRUSTEE.

John Slater, F.R.I.B.A.

On the motion of MR. CARMICHAEL THOMAS a vote of thanks to the scrutineers was carried unanimously.

The meeting then adjourned.

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FRIDAY, JULY 13, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICE.

CHAIRMANSHIP OF COUNCIL.

On MONDAY, JULY 9th, at their first meeting in the new session, the Council re-elected LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman for the ensuing year.

PROCEEDINGS OF THE SOCIETY.

TWENTIETH ORDINARY MEETING.

WEDNESDAY, MAY 9TH, 1923.

MR. D. MILNE WATSON, M.A., LL.B., Governor of the Gas Light and Coke Company, in the Chair.

THE CHAIRMAN, in introducing the reader of the paper, said that not only had he stood on many previous occasions before audiences in that room, but his important position at the Imperial College of Science and Technology at South Kensington and his work on the Fuel Economy Committee of the British Association kept him prominently before all those who were interested in the conservation of coal. He had been engaged in the study of fuel problems from his early days and he had for many years now been guiding the thoughts of young engineers and chemists towards methods for the more economical use of fuel so as to reduce waste and prolong the period during which our most valuable national asset would remain available. In the course of that work he appeared to have become specially attracted by the action of an incandescent surface on mixtures of gases, with the result that he had given to the subject many years of painstaking study. Surface combustion was thus a subject which he had made specially his own and was one with which his name would be forever associated. Previously to his researches, it was known that a hot surface had the power of increasing the rate of combination of gases below their ignition point; but Professor Bone showed that surfaces at temperatures above the ignition point combined them to a still greater degree and with increasing effect with increasing temperatures, such as were obtained by an intimate mixture of gas and air in explosive proportions. By the development of that process he had been successful in converting a large proportion of the potential energy of gas when burned immediately into radiant form and further in continuing the production of surface combustion into a bed consisting of granular refractory material. Great advantage was obtained from that latter process in the gaseous firing of multi-tubular boilers. By introducing that system of combustion in the tubes of the boiler, efficiency was largely improved, greater evaporation per square foot of heating surface was obtained and more steam produced per cubic foot of gas used, while no brick setting or expensive foundation was necessary. The size of the boiler was, of course, comparatively smaller. An increase in the efficiency of gaseous firing, by whatever means it was brought about, and whatever direction it took, was extremely important at the present time, as it must increase the tendency to a reduction in the use of solid fuel and prove another step in smoke abatement, in which direction Professor Bone's work had proved very helpful. His study of surface combustion and the great number of interesting experiments which he had made had no doubt done much to elucidate several problems connected with it. The experiments had attracted a great deal of attention. In both America and Germany much interest had been shown in the proposals: and experiments had been instituted and plant had been installed for their adoption. The fact that surface combustion was apparently flameless combustion, for he (The Chairman) believed that although the flame was not visible it was there, and also that radiant heat was present in a form from which it was easily and conveniently transferred, was one which made the subject very attractive for many purposes and further developments might be safely expected. Some time ago Professor Bone indicated that there were many points in the mechanism of surface combustion still to be explained and that many years would be required to realise the wide range of industrial possibilities for which it was suitable. He (the Chairman) would not be surprised if those present learned that evening from the apparatus before them of some of the further applications of surface combustion.

The paper read was :—

SURFACE COMBUSTION, WITH SPECIAL REFERENCE TO RECENT DEVELOPMENTS IN RADIOPHRAGM HEATING.

By WILLIAM A. BONE, D.Sc., Ph.D., F.R.S.,

Professor of Chemical Technology at the Imperial College of Science and Technology, London.

INTRODUCTION.

When I had the honour nine years ago of delivering in this place a series of Howard Lectures upon "Surface Combustion," I related both the history of the subject and my own researches upon it, culminating in the discovery, about the year 1909, of the phenomenon termed by me "flameless incandescent surface combustion," as conditioned by the catalysing powers of incandescent refractory solids generally. This phenomenon was demonstrated and exemplified in the then new processes of "diaphragm" and "incandescent bed" heating respectively, which had been experimentally developed by me in conjunction with the late Cyril Douglas McCourt. I am here to-night for the two-fold purpose of re-affirming what I then said concerning incandescent surface combustion as being for many purposes the most economical and advantageous method of developing and applying radiant energy by gaseous combustion that science has yet discovered, and of describing and demonstrating some recent developments in the manufacture of "radiophragm" appliances, which it is anticipated will soon lead to a rapid extension of the system in both the domestic and the industrial fields.

THE PRINCIPLE OF INCANDESCENT SURFACE COMBUSTION AND SOME HISTORICAL OBSERVATIONS THEREON.

Seeing that so many years have elapsed since my last public lectures upon the subject—years in which progress has been hindered by the great war, by the much-lamented death on a Flanders battlefield of my gifted collaborator, McCourt, and by other circumstances that need not be detailed—it is perhaps desirable that first of all I should recall how the principle of flameless incandescent surface combustion was conceived as a definite phenomenon distinguishable from ordinary flame combustion and afterwards realised and applied by McCourt and myself in our well-known system. Indeed, it seems necessary at the outset to clear the air by reference to the historical aspects of the subject; because attempts have been made to obscure and misrepresent incontrovertible facts with regard to the origin and interpretation of surface combustion so that its basic principles are in danger of being lost sight of. Therefore, without further apology, I will endeavour briefly to re-state what these principles are, and how they were discovered.*

Undoubtedly the starting point was Sir Humphry Davy's well-known experiment (1817), in which he tried the effect of introducing a warm platinum wire into a jar containing a mixture of coal-gas and air rendered non-explosive by an excess of the combustible constituents. The wire immediately became red-hot and continued to glow until nearly the whole of the oxygen had disappeared.† But although Davy was the first to observe an instance of surface combustion, he was far from recognising that *all* incandescent surfaces are equally capable of effecting it; on the contrary, he believed that a metal surface (and preferably one of platinum) is necessary. Moreover, he never seems to have conceived of an *intensification* of flame combustion by such means.

During the period 1820-35, a number of distinguished chemists (Dulong and Thénard, Döbereiner, William Henry, Thomas Graham, Faraday and de la Rive) experimented upon the power possessed by solid surfaces generally of inducing the *slow* combination of combustible air-gas (or gas-oxygen) mixtures at temperatures below their ignition points. No experiments were, however, made during this period upon the far greater powers possessed by incandescent surfaces, the observations being confined to the inducing of slow combustion at much lower temperatures. The close of the period was marked by a celebrated controversy between Faraday and de la Rive (1834-5) as to the mechanism of such slow surface combustion. De la Rive regarded it as involving a series of rapidly alternating oxidations and reduction

* For a fuller statement of the historical aspects of the subject the reader is referred to the "Howard Lectures" delivered by the author in 1914 (Jour. Roy. Soc. Arts. Vol. LXII., pp. 787-92.

† Davy's "Researches on Flame."

of the surface, whilst Faraday contended that the function of the surface is to condense both the oxygen and the combustible gas, thus producing in the surface layers a condition comparable with that of high pressure.

It may be wondered why, after so auspicious a start, all interest in the subject evaporated after 1835 and was not revived for half a century. The researches of Deville upon the dissociation of steam and carbon dioxide, in which incandescent surfaces had been employed, had begotten the wholly mistaken notion that because such surfaces promote dissociation they must necessarily also hinder combustion. The late Frederick Siemens undoubtedly upheld this view, for he contended that in furnace design and construction the contact of burning gases with hot surfaces should be avoided, because (as he thought) such surfaces "interefere with the rapid motions of the gases necessary for combustion; and in the second place, they cause dissociation . . . . and by doing so, of course, a vast amount of heat is lost." Moreover, he said, "complete combustion is impossible whenever live or active flame is allowed to come into contact with any solid surface." Unfortunately for progress, the effect of Siemens' teaching upon contemporary thought was to obscure the real issue. For whilst it is undoubtedly true that a *cold* surface thrust into a flame may cool the combining gases in its vicinity below their ignition temperature, and so hinder combustion, yet an incandescent surface will always accelerate gaseous combustion, as the late Thomas Fletcher, of Warrington, rightly maintained. It may be recalled that in the year 1887 this pioneer of modern gas-heating appliances demonstrated to an audience in this room the possibility of realising a flameless surface combustion by directing a mixture of gas and air on to a large ball of incandescent iron wire; but, unfortunately, he does not seem to have followed the matter beyond this point.

Towards the close of last century, renewed interest in the influence of hot surfaces upon gaseous combustion was manifested among chemists, chiefly as the result of certain attempts of the late Victor Meyer and others to determine the ignition temperatures of explosive mixtures by a particular method, which were thwarted by irregularities in the results, caused by the then unsuspected large action of the hot walls of the containing vessels.

It was in the year 1902 that, in conjunction with Dr. H. V. Wheeler (now Professor of Fuel Technology at Sheffield University), I began systematically to investigate as a fundamental problem the accelerating influence of hot surfaces upon combustion.* And as the subsequent technical developments have been based upon principles discovered or elucidated during a series of scientific researches carried out under my direction by a succession of skilled collaborators† during the past twenty years, I think it right to draw attention to what I consider the more important features of our work.

By the year 1907 I had succeeded in proving (1) that at temperatures below the ignition point all hot surfaces have the power of accelerating gaseous combustion in varying degrees according to their chemical character and physical texture; (2) that whenever a mixture of combustible gas and oxgyen (or air) is combining in contact with such a hot surface, the chemical action mainly occurs in, and is usually confined to, the boundary layers between the gaseous and solid phases wherever these may be in contact; and (3) that not only does the accelerating influence of a hot surface upon combustion rapidly increase with the temperature, but also that the differences between the powers of various surfaces, which at low temperatures are often considerable, diminish with ascending temperatures until at bright incandescence they practically disappear; and (4) that all such surface combustion, whether at high or low temperatures, depends upon an absorption of the combustible gas, and probably also of the oxygen, by the surface, whereby it (or they) becomes "activated" by association with the surface.‡

Such considerations led me soon afterwards (1907) to conclude that if an explosive gaseous mixture be either injected on to, or forced through the interstices of, a

* For this early work *vide* Phil. Trans. Roy. Soc. (1906) A.206 pp. 1 to 7.

† Dr. H. Hartley, Messrs. G. W. Andrew, A. Forshaw, A. Robson and others.

‡ In the year 1916 Dr. Irving Langmuir, who at the time (as he has since admitted) was unaware of my said previous researches, published a theory concerning chemical actions of surfaces (heterogeneous catalytic reactions) which included some of the basic ideas originally put forward by me; in a private communication to me, written after the discussion upon Catalysis which took place in London on 20th September, 1921 under the auspices of the Faraday Society (Trans. Far. Soc., Vol. XVII (1922) pp. 546-675). Langmuir acknowledged that "the general view point which you had in 1906 was much ahead of others of that time, and is in many ways closely related to that which I have developed independently from a rather different experimental basis."

porous refractory incandescent solid under suitable conditions, a greatly accelerated combustion would take place within the boundary layers between the gaseous and solid phases, wherever these might be in contact, and that the heat developed by such intensified combustion would maintain the surface in a state of incandescence without any development of flame, thus realising the idea of *a flameless incandescent surface combustion.*

Unfortunately, certain circumstances connected with my duties at Leeds University precluded for a while my developing this idea further. But when, in October, 1909, I was able to resume its pursuit, the late C. D. McCourt became my collaborator, and our subsequent technical researches (1909-1912) were carried out in association with Messrs. Wilsons and Mathiesons, Ltd., at whose works in Leeds our experimental station was located. The problem which McCourt and I then set out to solve was defined by me in October, 1909, in the following terms :—

"To bring a combustible mixture of gas and air in suitable proportions into contact with the interstices of an incandescent porous solid of suitable composition and porosity in such a manner as to produce a flameless, or as nearly as may be flameless, surface of interstitial combustion whereby the porous solid shall be maintained in a continual state of incandescence."

The resulting system of incandescent surface combustion which we conjointly worked out and demonstrated during the years 1909 to 1912, inclusive, comprised principally two processes, in both of which a homogeneous explosive mixture of gas and air in the proper proportions for complete combustion or with air in slight excess thereof, was caused to burn catalytically without flame in contact with a granular incandescent solid, whereby a large proportion of the potential energy of the gas was immediately liberated in a radiant form. And all subsequent developments, whether in this country or abroad, have embodied our original principle without essential change. Constructional modifications adapted to particular circumstances and conditions may have been made from time to time,—*e.g.*, variations in the precise way in which the explosive mixture is brought into contact with the incandescent surfaces, or alterations in the form of injectors—but these have not involved any change in the underlying principle of the combustion process itself.

Perhaps I may be allowed at this point to re-state and draw attention to the advantages claimed for our system of incandescent surface combustion over the older practice of flame combustion. First of all, the combustion is accelerated and intensified by the incandescent surface and can be concentrated just where the radiant heat is required. Second, the combustion is perfect with the minimum excess of gas. Third, the attainment of very high temperatures is possible without the aid of regenerative devices. And further, owing to the large proportion of radiant energy developed, transmission of heat from the seat of combustion to the object to be heated is very rapid and efficient. I may perhaps be excused some feeling of enthusiasm for my child ; but I trust it is so tempered by my scientific outlook that it does not warp my judgment. I will venture to re-affirm my belief that a perfect and intensified combustion is so combined in our system with a high radiant efficiency and rapid heat transmission that, when rightly understood and intelligently applied under proper auspices and direction, it is bound in the end to win its way and to become for many (if not most) purposes the premier one.

It is no part of the purpose of this paper to recount all the numerous applications of "surface combustion" which McCourt and I introduced before our more active connection with the enterprise ceased when the war broke out. They are recorded in the lectures which I gave on the subject during the years 1911 to 1914, inclusive, before some of the leading scientific and technical institutions in this country, America and Germany.* For the moment it will suffice for me to recall that, in addition to the experimental demonstrations of the principle of surface combustion and its manifold applications, which were given, both in connection with the said lectures and at our experimental station, we successfully installed and put into operation (*inter alia*) some large furnaces with regenerative systems, and two large boilers fired by coke oven gas at the Skinningrove ironworks which were in constant commission for several years, until the installation had ultimately to be dismantled to make room

* Jour. Franklin Institute, 1912; Ber. den Chemt. Ges., 1913, pp. 5 to 28; Proc. Royal Institution, and Howard Lectures on "Surface Combustion," 1914.

for other more urgently needed war plant.

It is not, however, the past with which I wish mainly to deal in this paper, although after the lapse of so many years it is necessary to recall what had been achieved up to the outbreak of war, about which time the immediate technical direction of matters passed out of my hands. Soon afterwards my gifted colleague, McCourt, relinquished surface combustion work for a commission in the Army, hoping that in such capacity his scientific training and knowledge of men would better serve his country and the cause of humanity. Alas, he was soon to be numbered among the deathless band who made the supreme sacrifice; he laid down his life for us while gallantly leading, as bombing officer, an attack on the German lines in France during the night of 8th October, 1916. *Mors janua Vitæ.* As one whose great privilege it was to enjoy his collaboration and close friendship during some years of fruitful pioneering research, I desire to pay my heartfelt tribute to his fine character, experimental skill, and devotion to the scientific ideal of truth and service. His death was, indeed, a great blow to the prospects of "surface combustion," which he had done so much to advance.

Apart altogether from such an unlooked-for calamity, and the urgent claims of war-work upon those of us who remained, it was perhaps hardly to be expected that the numerous minor difficulties of design and organisation, which inevitably arise when a new and far-reaching principle, such as surface combustion, has to be adapted to large-scale industrial operations, would be overcome in a day. After the first flush of success with such an invention, when unusual interest is aroused, and an embarrassingly large number of possible applications of it are thrust upon its authors from every quarter, there often follows a period during which a series of small and subordinate problems of detail, none of them very difficult, but in their cumulative effect seriously delaying, have to be patiently investigated. Indeed, in scientific invention there is rarely any "open Sesame" to complete success, which in most cases is only finally achieved after the expenditure of much time and effort.

Small wonder, then, that progress with "surface combustion" in this country has been impeded by the war and other adverse circumstances. I understand that in the United States it has been successfully developed in connection with large-scale industrial furnaces by, or through, the organisation which acquired the American rights shortly after my lecture in that country in the autumn of 1911. Some reference to this was made in the concluding chapter of my book on "Coal and its Scientific Uses" (1918), as well as to the results of a highly satisfactory test reported in 1916 by the U.S. Bureau of Standards to the Franklin Institute of Philadelphia upon the combustion conditions and high temperatures (1675° C.) attained with a surface combustion furnace for laboratory purposes. It is gratifying to know that the fire which we kindled across the Atlantic now more than ten years ago has continued to burn there with an increasing radiance appropriate to surface combustion.

Nor have things stood still here; for we are now in a position to announce a recent important advance in the method of making "radiophragms" for surface combustion appliances which bids fair to put diaphragm heating into an unassailable position and greatly to extend its scope and usefulness. We owe this improvement mainly to the patient labours of Mr. F. J. Cox, M.I.Mech.E., who, in conjunction with Radiant Heating, Limited (the organisation which originally pioneered "surface combustion" during the years 1910-12), has undertaken the further development of this branch of the enterprise. I now propose to explain its nature and significance; and at the conclusion of the paper Mr. Cox himself will demonstrate it to you.

Recent Developments in Radiophragm Heating.

In the first of the two processes evolved by McCourt and myself in 1909—which was termed the "diaphragm" process—a homogeneous mixture of gas and air, in the right proportions for complete combustion, was made to flow from a suitable feeding chamber at the back, through a porous diaphragm of refractory material, and caused to burn without flame at the surface of exit, which was thereby maintained in a state of red-hot incandescence. Such incandescent "diaphragms" were exhibited at my public lectures during the years 1911 to 1914 inclusive, and in some respects, perhaps, afford the most perfect and conclusive demonstration which could be devised of the reality of "surface com-

bustion'' as a definite phenomenon. We will presently show you such a diaphragm in operation, when you will be able to judge for yourselves of its significance and potentiality as a method of developing and applying a high degree of radiant energy by gaseous combustion.

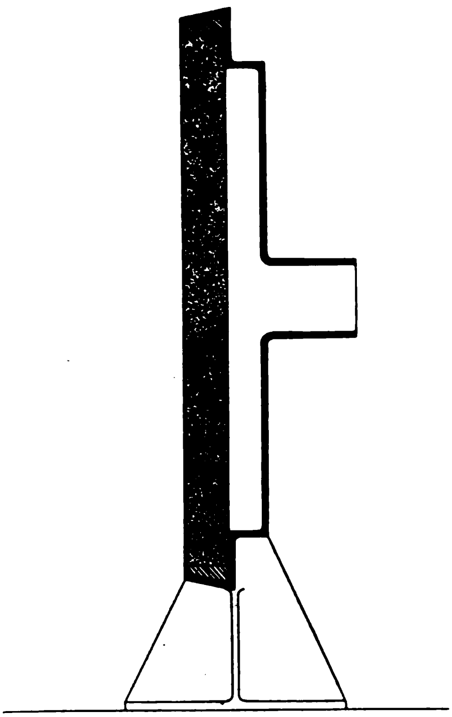

Fig. 1.

The diaphragm (Fig. 1) was made of granules of firebrick bound together into a porous and coherent slab (thickness $= 1\frac{1}{2}$ inches) by the addition of a small proportion of a suitable cementing material, whilst its porosity was *graded* to suit the particular kind of gas used. Each diaphragm was suitably mounted on a casing; the space between the back of the casing and the diaphragm constituting a convenient feeding chamber for the gaseous mixture. When such a diaphragm was operating, the actual combustion was confined to a thin layer—$\frac{1}{8}$ inch to $\frac{1}{4}$ inch only—immediately below the surface of exit, which was thereby maintained in a state of red-hot incandescence, no heat being developed in any other part of the apparatus.

As will readily be understood, this constituted a most efficient and economical method of developing radiant heat, the combustion being both instantaneous and perfect, and the area of the radiating surface bearing a very high ratio to what may be termed the combustion depth. I recently suggested the term ''*radiophragm*'' as a suitable designation for such a ''*radiating diaphragm*,'' and by this term it will henceforth be known.

Now, although in the new "radiophragm" developments referred to, there has been no departure in principle from the old procedure, an important advance has been made in the fabrication of the radiophragm itself, which confers very definite new advantages not realised before. And in order that you may better appreciate the significance of the change in question, I may perhaps be allowed to enlarge upon the conditions which experience has shown to be requisite for the complete and assured commercial success of radiophragm-heating. In the first place, the method of making the radiophragm should be such as will ensure not only perfect regularity of texture and porosity, but also a certain gradation of granules from back to front in relation to the quality and pressure of the gas used, so that the resultant radiation on the surface when the appliance is in operation shall be quite uniform. By the method formerly employed, the attainment of such conditions was found in practice to be rather uncertain, and a small proportion of the resulting radio-phragms had usually to be discarded, because on trial they did not quite come up to the desired high standard of uniform radiance. Nevertheless, it produced a large proportion of good radiophragms of almost any desired area, which in operation gave a uniformly incandescent surface, and did not back fire when run on explosive mixtures of coal gas and air so long as the appliance was freely radiating. Indeed, radiophragms were kept running for whole days in succession at our experimental station in Leeds—the largest one having an area of four square feet—with never a sign of back firing when freely radiating into the room.

The chief limitation, however, of the old radiophragms lay in the fact that, if their free radiation was by any means so impeded as to allow of too great an accumulation of heat in the incandescent surface layer which constituted the seat of the intensive catalytic combustion, the latter might in time heat up the next-under granular layer to such a degree as to render it in turn capable of promoting the catalytic combustion. The latter would then leave the surface layer

and commence in the one below it. It was thus possible, in circumstances of sufficiently restricted radiation, so to accumulate heat in the incandescent surface layers as to cause the seat of the intensive catalytic combustion originally set up therein gradually to creep backwards from layer to layer in the radiophragm until pre-ignition of the mixture ultimately occurred in the feeding chamber. As a matter of fact, the actual temperature of the incandescent surface when such an appliance is radiating freely into space does not exceed 900° C., and it was found that up to 1,000° C. (but not much beyond) there was no risk of back firing in the manner referred to.

than half what it formerly had been when the pans were heated over ordinary atmospheric flames. The secret of such economy lay in the fact that, whereas when gas flames are so used for boiling solutions in metallic vessels the heat transmission is greatly impeded by the non-conducting layer of relatively cool gaseous products which forms between the flames and the under surface of the pan, with an incandescent radiophragm the large percentage of radiant energy developed is instantaneously absorbed by the vessel and transferred to the liquid with high efficiency. The firm operating the battery of radiophragms in question reported them as being "very

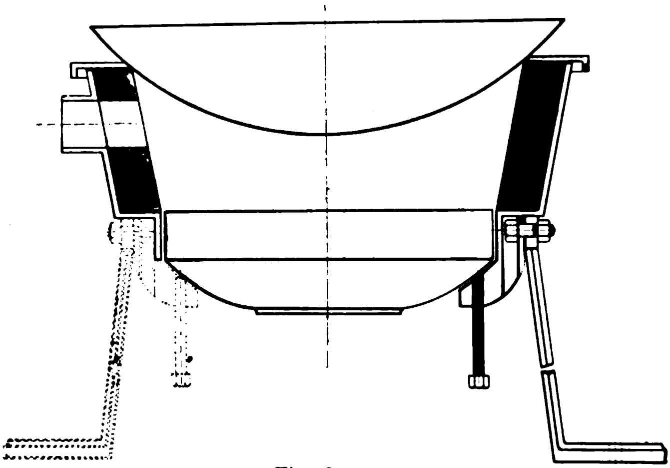

Fig. 2.

economical in the amount of gas consumed, and in every way satisfactory for our work"; and at the Bonecourt Company's offices there was exhibited a radiophragm which had been in use for the boiling of sugar solution for a period of eleven months, during which it had made 3,000 boilings, each of twenty minutes' duration, with a total consumption of 100,000 cubic feet of town's gas. In such cases, evidently, the absorption of the radiation by the copper vessel containing the sugar solution was sufficiently rapid to prevent any undue accumulation of heat in the outer incandescent layers of the radiophragm, so that back-firing did not occur. This may be regarded as a good example of what the old radiophragms were capable of in continuous use; otherwise their use was admittedly subject to the limitation already mentioned.

Notwithstanding the said drawback, however, a number of the old radiophragms, selected for the purpose, were successfully employed some years ago for boiling and concentrating sugar solutions on a commercial scale in a well-known confectionery factory. The apparatus employed (Fig. 2) comprised a 13-inch circular radiophragm surrounded by a brickwork setting, on which the copper pan containing the sugar solution rested. The supply of combustible gaseous mixture was controlled by one lever, which operated in a single movement the gas and air cocks, the ignition being effected automatically by means of a small pilot light. When I visited the factory in 1914, a battery of thirteen such units was in operation with good results. Each unit did ten to twelve heats lasting about twenty minutes each per diem, and some of the radiophragms had been in continuous daily use for about a year. I was told that the gas consumption (40 cubic feet per unit per hour) was not more

Thanks, however, to the persistent and painstaking efforts of Mr. Cox, who in

recent years has devoted much time to the detailed study of the texture, grading, and manufacture generally of radiophragms, all the former limitations to their use have been at length successfully overcome; and they can now be produced in quantity by his new method with complete certainty and precision, and of such a uniform texture and graduation of granules that no back-firing ever occurs, however much the radiation from the incandescent surface may be impeded.

I am not at liberty to disclose the way in which Mr. Cox makes the new radiophragms; but having seen his methods, I can testify to their thoroughness and reliability. Some of his radiophragms have been subjected to very drastic tests to prove their absolute immunity from back-firing, however much radiation is impeded, and the heat thereby accumulated in the outermost incandescent surface. In a recent test, made in America, the surface was raised to such a degree of white hot incandescence that the surface layer began to flux without any signs of back-firing; and I have myself seen tests in which there has been a much greater accumulation of heat by impeded radiation than the old radiophragms would have withstood without back-firing. Moreover, it is now possible to have two radiophragms operating with their incandescent surfaces opposite each other, a short distance apart, without either of them back-firing—a circumstance which was formerly impossible. I therefore think that Mr. Cox's innovations constitute such a radical advance in the manufacture of radiophragms as will make all the difference between their now comparatively limited and their ultimate extensive use in industry. And as the original inventor of the "radiophragm method" of realising surface combustion, I gladly acknowledge that Mr. Cox seems finally to have solved for us the problem of the apparatus, and that in all likelihood, through his new radiophragm, my "surface combustion" process will at length come into its own.

I will presently ask Mr. Cox to start up one of his new radiophragms, so that you may see how it operates. Specimens of the old and new radiophragms are on the table, so that you may have an opportunity afterwards of comparing them. One thing you will notice is that Mr. Cox now usually makes the radiophragms with slightly a corrugated surface, although this is not an essential feature of them.

Another minor difference between the old and new radiophragms, arising chiefly from their different textures, is that the new ones take longer time to reach their full incandescence than did the old form; but this is quite an unimportant consideration. When they reach full incandescence, both radiophragms exhibit equally well the phenomenon of flameless surface combustion, and there is no perceptible difference. The most important difference is, as I have already stated, the fact that in Mr. Cox's new radiophragm no creeping back of the combustion ever occurs, however much the radiation is impeded and heat thereby accumulated in the outermost surface.

As a proof that the world at large is recognising the value of these improvements, I may say that already Radiant Heating, Limited, has fitted up numerous large restaurants in London and elsewhere with radiophragm installations complete with all accessories for grilling, toasting and cooking purposes, with such success that large repeat orders have been placed and are being executed.

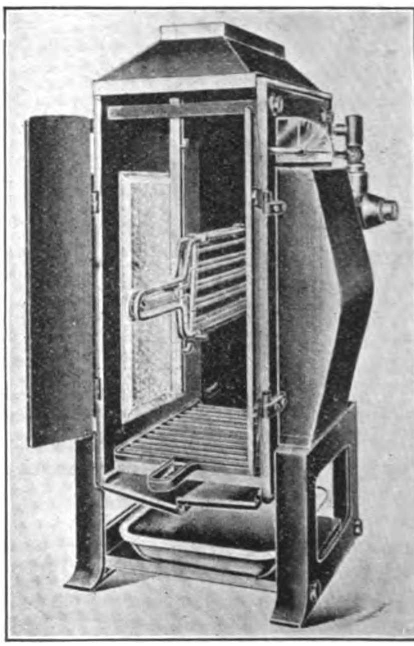

Fig. 3.

To illustrate the type of appliance which is included in such installations, I will now show on the screen a picture of a small griller (Fig. 3) fitted with two radiophragms each 20 inches by 8 inches, working opposite

each other at a distance of 8 inches apart. The articles to be grilled (or toasted) are placed in a sliding grid midway between the two radiophragms, so that both sides of them are cooked equally and simultaneously. This arrangement of radiophragms and grid is enclosed in an oven-like casing, which also carries the feeding chambers for the radiophragms, as well as the necessary arrangements for mixing the gas and air. And if desired a small fan-blower, electrically driven from a wall plug, can be attached to give the requisite pressure to the combustible mixture when other means are not available. Such an appliance is capable of grilling 120 steaks or chops per hour, with a gas consumption of only 80 cubic feet. The next slide (Fig. 4) shows one of two batteries of four large grillers, similarly constructed, which will shortly be installed for use in connection with one of the largest restaurants in London. Each unit in the battery is fitted with four pairs of radiophragms each of which measures 20 x 5 inches, and four sliding grids. The supply of gaseous mixture

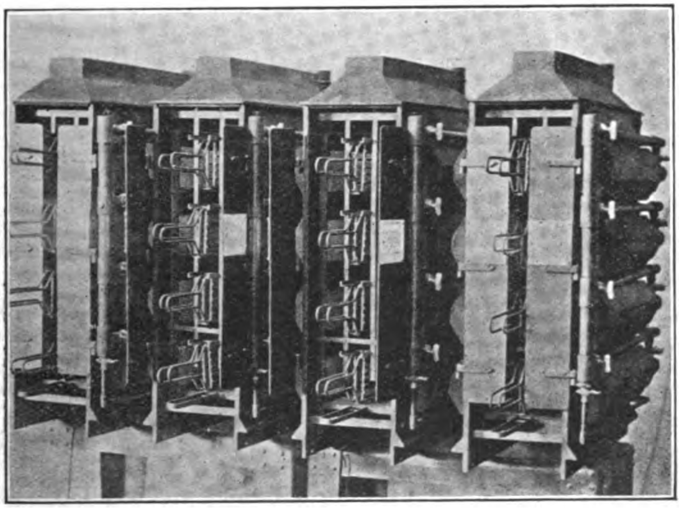

Fig. 4.

to each pair of radiophragms is under separate control, and the whole battery of four such grillers will be capable of grilling 1,000 steaks per hour.

About a fortnight ago, I had the pleasure of visiting a large public institution in the country not far from London, where 130 adult persons are housed and provided for, in which all the cooking has been done for seven months past by radiophragms operated by petrol-air gas, to the entire satisfaction of the management. Mr. Cox has also designed for an hotel in the Midlands a jack roasting appliance, whereby, with the aid of the new radiophragms, he hopes to bring back "the roast beef of old England" in place of the oven-cooked joints, which for many years past we have had to put up with. I feel sure that those present who are old enough to remember the quality of the roast beef produced forty years ago by a jack in front of an open fire will wish him success in this direction.

Turning to the industrial field, some biscuit and confectionery factories have been equipped with specially designed automatic machines using gas-fired radiophragms as their sole source of heat. Appliances for lead-melting, type-founding, the hardening and tempering of metals, and for many other purposes, have been constructed and are at present on trial. As some of these will be referred to again during the subsequent demonstration, I need not now enter into any detailed description of them.

CYLINDRICAL RADIOPHRAGMS FOR WATER HEATING AND SUPER-HEATING PURPOSES.

So satisfactory is the new method of manufacturing radiophragms that we have recently succeeded in producing a hollow cylindrical form which promises to be applicable for water-heating and steam-raising purposes. I may here say that McCourt and I always had in mind the possibility of making such

hollow cylindrical radiophragms, but not until Mr. Cox worked out the new method has the attempt proved successful.

Obviously there are advantages to be gained by the use of such radiophragms in appliances of a tubular type for the aforesaid purposes; and although we have not as yet had time to investigate them fully, we intend doing so in the near future. Mr. Cox will presently show you a hollow cylindrical radiophragm (12 inches long and 2½ inches in diameter) fixed co-axially in a 3 inch steel tube surrounded by water in an open trough, so that you may see how it works. The mixture of gas and air in proper proportions for complete combustion is fed through a pipe into the hollow part of the radiophragm, and after passing through its walls is burnt flamelessly in its outer incandescent surface. The radiation thus emitted is instantly transmitted to the adjacent wall of the iron tube, through which it is conducted to the water on the other side.

rapid heat transmission and high thermal efficiency, with the original Bonecourt fundamental boiler fire tube; but it is being tried experimentally, and on some future occasion I may be able to say more about it. It should also be possible to adapt the hollow cylindrical radiophragms fixed in such tubular appliances for the super-heating of steam in gas-fired boilers, a very importan consideration.

Surface Combustion Boilers.

I am loath to conclude this paper without some reference to the subject of surface combustion boilers; for although I must reserve its fuller treatment for a future occasion, it behoves me now to shew how it stands and the direction in which I look for developments. Also, some misconception may have arisen since last I had an opportunity of addressing an audience upon it, which perhaps my remarks may help to remove.

The seeming satisfaction of the engineering

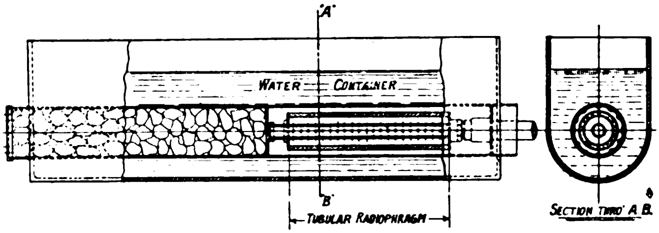

Fig. 5

In Fig. 5 is shown an experimental unit of what ultimately may be a new surface-combustion water-heating or steam-raising device, consisting of a steel tube (3ft long by 3 inches in diameter) surrounded by water, in which are arranged (a) such a hollow cylindrical radiophragm as I have described (1ft. long by 2½ inches diameter), in the outer incandescent surface of which the gaseous mixture is burnt without flame, and (b) a packing of granular material or the like about 18 inches in length. The latter serves to baffle the hot products of combustion, and to make them impinge repeatedly with high velocity against the walls of the tube (as in the original Bonecourt boiler), thus materially accelerating their cooling, and preventing or minimising the formation of the "dead film" of relatively cold gases, which in ordinary boiler practice so seriously hinders the heat transmission. It would be premature to predict how such an arrangement will compare, in respect of

world with the poor heat transmission and thermal efficiency realised in present-day boiler design and practice is to me surprising. In the case of stationary land boilers of the Lancashire or water-tube type, the engineer seems content with an hourly evaporation of from 5 to 8 lbs. of water "from and at 212° F." per square foot of heating surface, together with a thermal efficiency rarely exceeding 75, but too often considerably less than 70 per cent. When it is realised that such a low rate of evaporation represents a heat transmission of *less than* 1 *per cent.* of the maximum conducting capacity of the boiler tubes,—assuming an average difference of 1000° F. between the mean temperature of the products of combustion passing through the tubes and that of the water surrounding them,—it is at once evident how wide a margin there is for improvement.

This unsatisfactory state of affairs is principally due to the formation, on the

underside of the tube, of a feebly conducting and practically stagnant film (almost one-fortieth of an inch thick) of gas at relatively low temperature which, in most of the existing types of boilers, opposes a strong resistance to the transmission of heat from the burnt gases to the water. Thus my colleague, Professor W. E. Dalby, has calculated that of the total "temperature head" almost 97 per cent. is required to overcome the resistance of the gas film, a further 2 per cent. to overcome the resistance of a similar water-film on the other side, leaving only 1 per cent. effective as regards heat transmission across the metal of the tube.*

About the time that McCourt and I first turned our attention to the possibilities of gas-fired surface combustion boilers, the late Professor Nicholson of Manchester, in following up the researches of Osborne Reynolds upon heat transmission, demonstrated that the retarding influence of the gas-film may be diminished by increasing the velocity of the burnt gases through the boiler tubes or flues. But it is not yet sufficiently recognised by engineers that, inasmuch as gases are practically transparent to radiant heat, the fullest possible use should be made of radiation in boilers. For, as far as its influence upon radiant energy is concerned, the "dead gas-film" may be considered as non-existent.

Now, in the gas-fired surface combustion boiler invented by McCourt and myself twelve years ago, the combined advantages of the Reynolds-Nicholson principle of high gas velocities and of radiant heat were realised in (as I believe) a quite unparalleled manner. And in view of the inadequate appreciation there has been of the significance of the results which we obtained, I will ask your indulgence whilst I recall them now.

Our first experiments were made with a single steel tube 3 ft. in length and 3 inches in diameter, packed with fragments of granular refractory material, meshed to a proper size, and fitted at one end with a fire-clay plug through which was bored a circular hole ⅜" diameter, for the admission of the explosive mixture of gas and air at a speed greater than that of back-firing. This tube, which may be termed the fundamental unit of our system, was fixed in an open trough containing water, like the one now exhibited on the table.

* "Heat Transmission," by W. E. Dalby, Proc. Inst. Mech. Eng. 1909, p. 939.

Experimenting with such an arrangement, it was found possible to burn completely a mixture of 100 cub. ft. of the then Leeds coal gas plus 550 cub. ft. of air per hour, and to evaporate about 100 lb. of water from and at 212°F. per hour (20 to 22 lb. per sq. ft. of heating surface), the products leaving the further end of the tube at practically 390°F. This meant the actual transmission to the water of 88 per cent of the net heat developed by the combustion, and an evaporation per square foot of heating surface nearly twice that of an express locomotive boiler. The combustion of the gas was completed within 4 or 5 in. of the point where it entered the tube. Of the total evaporation, no less than 70 per cent. occurred over the first linear foot of the tube, 22 per cent. over the second foot, and only 8 per cent over the last foot. This pointed to a very effective "radiation" transmission from the incandescent granular material in the first third of the tube, where the zone of active combustion was located, although it should be remarked that the loci of actual contact between the incandescent material and the walls of the tube were so rapidly cooled by the transmission of heat to the water on the other side that they never attained a temperature even approaching red heat. The granular material in the remaining two-thirds of the tube served to baffle the hot products of combustion and to make them rapidly impinge with high velocity against the walls of the tube, thus materially accelerating their cooling, and preventing the formation of any dead "gas film."

From this initial experiment we proceeded to construct our first experimental boiler, which was made of ten such tubes fixed horizontally in a cylindrical steel shell capable of withstanding a pressure of over 200 lb. to the square inch. This small boiler was connected with a small tubular feed water heater containing 9 tubes, each 1 ft. long and 3 inches diameter, similarly packed with granular material to facilitate the exchange of heat.

With this simple combination of boiler and feed water heater we were able, on a measured independent trial by a party of German engineers in London, to transmit to the water 93.3 per cent. of the heat units contained in London coal gas of 510 B.T.U. net per cubic ft. at N.T.P. and to obtain an average rate of evaporation of no less than 33.9 lb. water per square ft. of heating surface per hour (from and at

212° F.). The steam gauge pressure was 103 lb. and the products of combustion left the feed water heater at a temperature of 289° F. I venture to think that so remarkable a result is probably unparalleled in the history of boiler trials.

Skinningrove Boiler for Coke-Oven Gas.

The success of this first experimental boiler enabled us to proceed immediately with the erection of a much larger plant drawn under suction from a fan, through a short mixing tube, into each of the said combustion tubes where it was burnt without flame in contact with the incandescent granular material. After leaving the boiler tubes the products of combustion passed onwards through a semi-circular chamber at the back of the boiler into a tubular feed water heater and from thence they were drawn by the fan which discharged them at a temperature of 95°C. into the atmosphere.

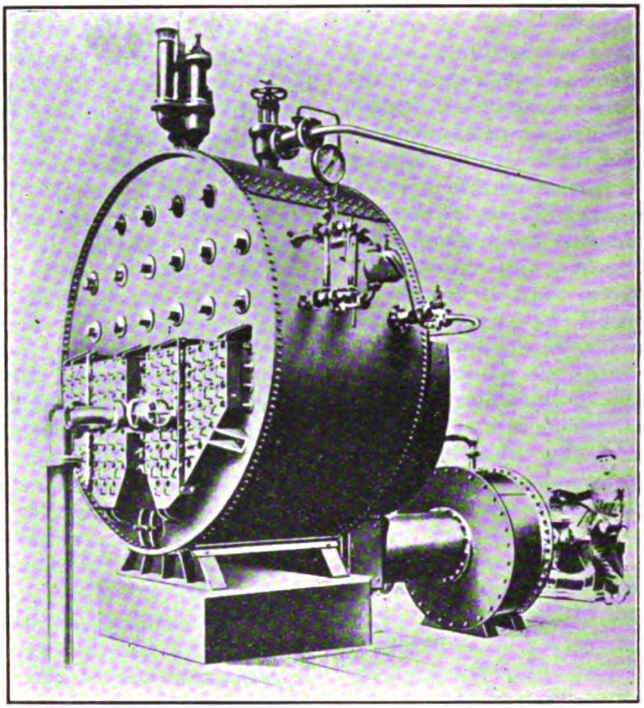

Fig 6.

(Fig. 6) on similar lines for coke-oven gas, at the Skinningrove Iron Works in the year 1911. It consisted of a boiler drum 10 ft. in diameter and 4 ft. from front to back, traversed by 110 steel tubes each of 3 inches internal diameter, packed with fragments of suitable refractory granular material. To the front of the boiler was attached a specially designed gas feeding chamber which delivered washed coke-oven gas, at the ordinary temperature and under a pressure of 1 to 2 inch water gauge, to each of the 110 combustion tubes. This gas, together with a regulated proportion of air from the outside atmosphere, was

In a series of trials carried out on the plant by an eminent American steam engineer who had been specially sent over the water to investigate the system in July, 1912, it was found that, even with the boiler unlagged and when raising steam at a pressure of 100 lb. only above that of the atmosphere, 92.7 per cent of the net heating value of the coke-oven gas was transferred to the water and sent out as steam, the overall evaporation being at the rate of 14 lb. per square ft. of heating surface per hour. The net efficiency of the boiler and feed water heater, after deducting the power required to drive the fan, was certified to be 90.2 per

cent. After so successful a trial a second boiler unit of similar size to the first was added to the plant.

As is often the case, the first attempt to translate a new idea of this kind into every day large scale practice was not altogether unattended with difficulties, the investigation of which taught me some valuable lessons. But the measure of success obtained over the period of about six years during which the installation of two boiler units put down was working quite came up to my own expectations, and may be considered as having proved the soundness and practicability of the principles involved. Perhaps it will be useful if I briefly summarise the experience gained.

First, and most important of all, no difficulty was ever experienced with the boiler part of the installation, nor yet with the gas-feeding and combustion arrangements. The high thermal efficiency and heat transmission already referred to was consistently maintained throughout and, owing to the rapid ebullition, the tubes kept clean and free from scale. There was also no trouble at all with priming. Moreover, notwithstanding the high rate of evaporation, the mechanical properties of the tubes were not in the least impaired. Indeed, in 1917, more than five years after the first two boilers had been started up, the testimony of the management to me was that "the boilers themselves have proved all that you claim for them in efficiency and reliability. . . ."

The only real difficulty met with in the installation arose out of the very efficient cooling of the products of combustion in the feed-water heater, and the consequent corrosive action of the small amount of sulphur oxides which they contained upon the outlet tube plate of same, and the fan mechanism beyond it. The average temperature of the products of combustion leaving the boiler when evaporating at a gauge pressure of 95 lb. per square inch was almost 385° F. or say within 15° F. of the temperature of the steam. At such temperature they had no corrosive action whatever upon the boiler tubes or plates. But in the feed water heater, as originally installed, their temperature was reduced to about 200°F., which was too low to prevent corrosive action upon metal surfaces. Consequently the outlet plate of the feed water heater and the fan mechanism beyond it suffered rather severely. Had this been foreseen at the outset, we should have either omitted the feed water heater altogether or installed a less efficient one, so as to keep the temperature of the gases entering the fan above 350°F. Such a precaution, together with the improved type of fans now available would probably obviate the difficulties referred to.

My attention having been drawn to two criticisms which have been made recently about the Skinningrove type of boiler, with your kind permission, I should like now briefly to answer them. It has been alleged that the use of the granular refractory packing occasionally gave trouble by breaking down owing to intense local temperatures developed by lack of free radiation from groups of particles ; but so far as my knowledge goes, this is untrue, and I do not believe it. The refractory packing was composed of irregular pieces of Glenboig fire-brick on the average about the size of a hazel nut, and so far as I am aware, it had not to be renewed more frequently than once a year when the boilers were laid off for the usual annual inspection. The other statement, to the effect that the use of an explosive mixture in the burners allowed back-firing to occur unless care was taken every time the burners were adjusted, is misleading; because the method of feeding the combustible mixture of gas and air on to the incandescent granular material in the front end of the fire tubes was such as precluded the formation of an explosive mixture anywhere except in the short mixing tubes (6 inches long by 1 inch diameter) leading into the fire-tubes, and then only for the last 2 or 3 inches before reaching the incandescent surface where the combustion took place. Such a short mixing tube was fitted into the fire-clay plug which formed the entrance to each of the 110 fire-tubes of the boiler, and only there in a very limited space (but nowhere else) could any explosive mixture possibly be formed.

Considering, then, all the circumstances of the case, and especially the fact that it was the first attempt to apply surface combustion to a large boiler fired by a dust-and-tar-free but H_2S-containing coke-oven gas, I venture to think that the Skinningrove experience proved all the really material claims made by McCourt and myself for our system. And profiting by the lessons that flowed from it, I would myself have no hesitation in now proceeding to instal large

boilers of the Skinningrove design, with some modification in detail, for either coke-oven or towns-gas, being confident of their exceptionally high thermal efficiency, rapid heat-transmission and smooth working.

It should be borne in mind that such unsurpassed results as I have referred to were obtained with a tubular boiler only 4 ft. long, and I am doubtful whether such concentrated and intensive steam-raising and high efficiency in gas-fired boilers are possible on any other than surface-combustion lines. Recognising the importance of the further investigation of the matter being pushed forward, I am hoping soon to take it up again, especially in view of the recent work of Mr. Cox on radiophragms, and we shall welcome assistance from the engineering profession. For my firm belief is that the more completely the ideal of a flameless surface-combustion, with its consequent high radiant effects, is or can be realised in gas-fired boiler design and practice, the greater will be the resulting rate of evaporation and thermal efficiency. And I am prepared at any time to maintain my convictions by appeal both to well-established principles of combustion and heat-transmission and to the logic of achieved and verifiable results.

DISCUSSION.

Professor H. E. Armstrong, F.R.S., in opening the discussion, said that he was sure that they had listened with very great interest to Professor Bone's modest and enthusiastic account of his progeny and its new pram. Personally, he could not help contrasting that evening with an unfruitful evening spent in the same place a few months ago when the subject of smoke abatement was under discussion. Lord Newton was in the Chair and those at the meeting heard a doleful story of the harm being done by smoke and the repressive measures that ought to be introduced in order to prevent it. He ventured to say on that occasion that what was needed was not punitive measures to prevent smoke but constructive work to make the production of smoke unnecessary. Professor Bone's paper was a first class example of the kind of constructive work required at the present time. He took a considerable interest in the matter because he used to urge upon Professor Bone the absolute need of improving on the miserable gas stove which then existed and which still exists. He had seen the early appliances which had been shown on the screen and he had spent several days with the boiler at Skinningrove. He had always understood that the only directions in which there had been failure were in the first place, the infant was deprived of Professor Bone's parental care at too early a period; in the second place, there was the back-firing; and in the third place there was the breakdown of the fan suction machinery. The assurance had been given that evening that the back-firing difficulty was at an end. If that were so, very great progress had been made. Personally, he had looked forward for years to the introduction of such appliances for domestic purposes. He thought that the present gas cooking appliances were miserably inefficient. He hoped that by means of the arrangement now introduced people would very soon get back to a rational and healthy system of cooking. There was not the least doubt that the present method was one which most seriously affected the food value of the food cooked. He would like to hear from Professor Bone later on something with regard to the improvements that had been made with a view to bringing the appliance into a condition suitable for domestic use. They had heard the air roar when the appliance was started; no one would want to have that sort of noise in his house and he would like to know how that difficulty was going to be surmounted. His own impression was that people would use electricity in the future to aid them in burning gas. He thought that most people were coming to the belief that the present method of illumination by electric light was a mistaken one and that gas was very superior as an illuminant. It so happened that only the previous evening friends who were in the habit of using electricity came to see him—he had a single South Metropolitan incandescent burner in action and they had remarked how superior the light was and how much pleasanter. He believed that, in the future, people would probably make use of electricity for the purpose of grinding out the air which was required to burn a proper gas. He thought that there was one other fact that ought to be mentioned in connection with the matter. The subject of smoke abatement was always coming forward. There had been correspondence in the previous week in *The Times* with reference to the way in which the plants at Kew were suffering from smoke and so on. A botanist pointed out that the plants were not suffering only from smoke but perhaps not so much from smoke as from sulphur dioxide. Probably, the sulphur dioxide in the air was doing infinitely more injury to vegetable life and to buildings than any smoke which was produced. He had recently been to Venice and other parts of Italy and he had marvelled at the wonderful way in which the marbles there had remained unaffected and retained their sharpness after several hundreds of years of exposure to the atmosphere. Only wood was used as a combustible. Wherever one went in Italy one saw no such evidence of the effect of smoke as one saw in this country. No doubt,

in the course of a few years, the sulphur in gas would be got rid of entirely. It only remained to reduce to a minimum the sulphur in the solid fuel which was used to produce a far greater improvement than would be produced by merely getting rid of the smoke. If the Gas Companies pursued an enlightened policy and recognised that it was for them to produce all the fuel required in forms as free from sulphur as possible a real millenium would be reached. He thought that the thanks of the meeting ought to be given to Professor Bone for the enthusiasm which he had displayed and for the way in which he had stuck to the problems of combustion when no one else had attempted to deal with them and for the success which had attended his efforts. He hoped that Professor Bone would realise that there was no subject upon which he could work that was of more importance from the public point of view. He proposed that the meeting should give its heart-felt thanks to the Author for his communication and congratulate him on the obvious improvements which had taken place.

(*A demonstration was then given by* MR. F. J. COX, M.I.MECH.E.)

MR. W. H. PATCHELL said that one was very glad indeed that Professor Bone was again taking care of his own child. He had been sorry that the radiant heat business had been lost sight of for so long, and it was a real pleasure to know that Professor Bone was going to re-handle it. Engineers, particularly those interested in boilers, had had before them the experiments made with locomotive boilers showing the relative evaporation of the different portions of the boiler. If the Author would turn back to some of the old curves he would find that they exaggerated the curve he showed in 1914 and reproduced in what he had described this evening. Something like 70 per cent. of the work of the locomotive boiler was done by radiant heat over the fire box and the end of the tube. In other words something like three-quarters of the work of the locomotive boiler was done by radiant heat. With that fact before them engineers had tried to screen boilers from radiant heat by putting in coking arches and all sorts of abominations. Those who tried to set boilers high were trying to get complete combustion before the gases reached the tubes and so put out the flame. They then had the chance of getting the radiant heat from the particles of solid fuel taken upwards in the gases and so got the benefit of the enormously high combustion chambers which a few used in England, but which had been more used in America. If the boilers were shortened, gases were taken away from the boiler at a lower temperature and there would be the danger of condensation on the water heaters, as the Author had said there was in the water heaters in connection with the experiments at Skinningrove. It was the capital cost and the average by which engineers lived. If they could all get 99 per cent. efficiency they would only have to get a little further forward and they would be able to live without work. Unfortunately they could not do that and they had to live by the average, so they had a long way to go before they could construe the terms of Professor Bone's experiments into terms by which they could generate power or any form of heat on a large commercial scale.

MAJOR W. GREGSON said that, as being very intimately connected with the modern Spencer-Bonecourt (Kirke Patent) gas-fired boiler which was the present day representative of the Author's original steam generator, he would like to make a few remarks on the modifications his firm had found necessary in order to adapt the boiler to everyday commercial use. He believed that he was correct in saying that a number of original boilers were still at work in their original form; but in adapting the boiler to the wider application of surplus industrial gas, it was first of all found necessary considerably to modify the burner arrangements. The original type of burner as described by the Author that evening meant individual setting per tube. In the case of some of the larger boilers constructed by his (Major Gregson's) Company, that would mean over 500 settings and they found in practice that it was essential to arrange the burners so that control could be effected with one main valve. That was particularly the case where varying loads had to be dealt with, or again, where varying gas pressure had to be allowed for. In the old type of burner it was found impossible in practice to prevent back-firing when dealing with those variations. Turning to the question of refractory packing in the tubes, with anything but perfectly clean gas the packing was found to retain the impurities. That meant that it acted rather like wool in a filter, and there resulted obstructions causing intense local heating which eventually caused the packing to fuse and at the same time added to the pull required by the fan. He heartily endorsed the Author's remarks with respect to feed water-heaters. His Company had abandoned those owing to the corrosion trouble referred to in the lecture. By re-designing the boiler heating surface it is now found possible to give the same efficiency with the boiler alone, as was originally obtained with the boiler *plus* feed water-heater. Dealing with the question of fans it would be noted that the Skinningrove boilers were worked with a 20 inch water-guage. That meant very specially designed fans that gave rise to certain mechanical troubles which were entirely absent from the new type of Spencer-Bonecourt boiler which operated on a four-inch water guage as a maximum and in certain cases on natural chimney draught alone. He would like to make it

perfectly clear that he was in no way disparaging the Author's work: in fact the Author had no more profound admirer than he; but he thought that the Author looked at the problem of steam-raising from the point of view of the chemical technologist, whereas his (the speaker's) point of view was that of the purely mechanical engineer. It was interesting to note that his Company's boilers retained the high efficiency of the Author's original boilers in spite of the rather drastic way in which the original principles had been dealt with. On the face of it his Company would have been prepared to sacrifice a little efficiency to ensure mechanical advantages, ease of control, low first costs and low maintenance charges; but fortunately practice had proved that it was possible to obtain all those desirable features and yet retain the original high efficiency. In his opinion the high efficiency of the present-day Spencer-Bonecourt boiler as distinct from the original Bonecourt unit was due to the intimate molecular mixing of gas and air in practically theoretical proportions in the small-diameter tubes, ensuring perfect combustion with very little excess air, coupled with proper proportioning of heating surface and high gas velocity.

Professor Bone, in reply, said that there were a great many points arising out of the paper which could have been usefully discussed had there been a special session for the purpose. Dr. Armstrong had inquired whether the radiophragm apparatus could be used without air under pressure. He (the author) believed that Mr. Cox was working at the problem, so that the matter was being kept in mind. The particular fan arrangement which had been used to provide the air pressure for the demonstration that evening was a makeshift one; with a permanent arrangement there would have been much less noise. Indeed, the appliances made by Mr. Cox were fitted with very small fans which could be run from a wall plug with a very low consumption of electricity and with practically no noise. There was no reason why in any house of all but the cottage size the appliances should not be used, for their cost was not prohibitive, and the current required was very small.

He particularly wished to take up the points raised about gas-fired boilers by Major Gregson, who claimed to have developed his (the author's) child. He was, however, decidedly of the opinion that Major Gregson had made a retrograde development. For, as stated in the paper, he believed that to obtain the best results one must adopt surface combustion; indeed he did not think it possible to obtain anything like such good results in the way of intensive evaporation combined with high thermal efficiency by any other system. By giving up surface combustion in their boiler designs, Major Gregson and his associates had (he thought) sacrificed some very important advantages. He ventured to predict that, if only surface combustion were properly applied from an engineering point of view to boilers, in due time it would become the premier method for gas-firing them. As to the question of the particular refractory packing used with the Skinningrove type of boiler, he was quite aware that it was applicable only when clean gas was available; and in fact, the Skinningrove boiler had been designed to burn clean coke-oven gas. He was also aware that in the event of boilers having to be fired by uncleaned gas, it would be necessary to have a different sort of packing from that adopted for the Skinningrove boiler. He did not think that Major Gregson's recent criticisms of the Skinningrove type of boiler were fair, for reasons stated in the paper; indeed, he regarded them as misleading. He wished to repeat that, having watched the Skinningrove boiler year in and year out, and on some occasions for hours together, he was in a position to deny emphatically that there had ever been any kind of trouble with that type of boiler using clean coke-oven gas, with the exception of the corrosive action of the cooled products of combustion upon the fan mechanism, which trouble was nowadays entirely preventable, as explained in the paper.

The Chairman said that he was sure that all those present had learned a great deal that evening; they had certainly all been very interested. Professor Bone was a master in lecturing; he made every subject interesting. He was sure they were deeply indebted to him for his most interesting lecture and for the experiments which he and Mr. Cox had brought before them. All that was left to be done was to accord a hearty vote of thanks to him.

The motion was seconded by Mr. W. H. Patchell and carried unanimously.

Professor Bone said that he hoped to take up again the subject of surface combustion and to pursue it continuously. It had been a great pleasure and a great honour to give the paper and the demonstration. He trusted that the fruits of Mr. Cox's labours would be for the benefit of the great industry to which they were all devoted.

On the motion of the Author a vote of thanks was passed to the Chairman and the proceedings terminated.

Mr. Henry Edmunds writes: I should have liked to take some part in the discussion on Professor Bone's paper, but had to leave early to catch a train. Many important developments have taken place since Professor Bone read his former paper on the same subject; but possibly the most important is the valuable solution of the diaphragm problem due to Mr.

F. J. Cox. I was with Professor Bone on his visit to America, when he gave a lecture at St. Louis before the Association of the United States Gas Engineers held in that city. I recollect that when the diaphragm shone out brilliantly owing to its surface combustion, it created quite a sensation, and was greatly admired by the many who witnessed it for the first time. There were, however, difficulties in producing uniform results; and, as Dr. Bone remarked, there were probably three out of ten, or possibly even a higher percentage that were un-uniform and unsuitable for effective use. This was a very serious limitation and added greatly to the cost of production. In addition, if the surface could not freely radiate there was always the risk of "back-firing," which in some cases might be disastrous. Further, the length of time for the kilning and seasoning were factors all of which greatly limited the use of the Bone-court diaphragm; so much so, that on my recent visit to the United States, where surface combustion has been developed on a profitable commercial scale by an organisation of considerable enterprise, they have not been able to make any use whatever of the original Bone-McCourt diaphragm for the reasons given above. Though very interesting, it was too uncertain and unreliable in its action. Mr. F. J. Cox was one of the first to use the Bone-McCourt diaphragm in connection with Air-gas, as illustrated in one of the diagrams at the lecture. Mr. Cox fortunately realised the limitations, and it is due to his persistent efforts that he has now successfully solved this problem. Not only are his diaphragms reliable with a hundred per cent. uniformity, but by his new method they can be made in a few hours, whereas the others required some days for their production.

In addition to this he has evolved a cylindrical type, which, for heating water, is probably the most effective form of realising surface combustion in steam raising.

The application of the radiophragm when once appreciated will be of great service to the gas interests all over the world, giving a clean non-oxidising high temperature surface under complete control.

CORRESPONDENCE.

THE LEPROSY PROBLEM.

When I was in India in 1914, I learnt how highly Sir Leonard Rogers was esteemed at that time for his discoveries and beneficent work, and since then he has advanced the cause of medical science with further great discoveries. So I lost no time, though far from home, in reading the *Journal* that contained his valuable paper on Leprosy.

I venture to add my humble contribution to the discussion.

Sir Leonard has pointed out how lepers conceal their disease with the result that children are born of leprous parents and inherit the taint, and this may be quite unknown to the person (medical man or other person) who vaccinates the child, and then takes matter from the child with which to vaccinate other children, according to the almost universal practice of 100 years, all over the world, until quite recently.

In this way leprosy was widely spread, and this accounts for its prevalence in many countries. The facts are set out very carefully by the late Mr. William Tebb in his book entitled, "The Recrudescence of Leprosy." Mr. Tebb travelled round the world and collected valuable information.

I am told that arm to arm vaccination has now been abandoned, even in hot countries, where difficulty has been found in keeping vaccine matter in tubes, as is now done in England. I certainly hope that this is a fact.

ARNOLD LUPTON.

NOTES ON BOOKS

A TEXT-BOOK ON THE ARTISTIC ANATOMY OF THE HUMAN FORM. By V. W. A. Parkes. London: John Bale, Sons & Danielsson, Ltd. Limp cloth, 7*s*. 6*d*. net; cloth boards, 10*s*. net.

This book should prove very useful to art students. It is divided into two parts, the first dealing with the skeleton, the second with the muscles. Every bone and muscle is carefully illustrated, and an index makes reference as easy as it can be. In addition to the author's illustrations, the book contains five reproductions after Michael Angelo, which clearly demonstrate his masterly knowledge of anatomy. The text gives a good description of each part and of the way in which it performs its functions.

There is only one thing in the book to which we are inclined to take exception, and that is Mr. Parkes's derivation of the word anatomy "from two Greek words, ανα τομαω, which signify 'to cut up,'" The verb τομ΄αω is exceedingly rare, and means not "to cut," but "to need cutting." It is derived from τομη΄, which again is derived from τε΄μνω, to cut, and, therefore, the derivation usually given is preferable to that suggested by Mr. Parkes. The matter is, no doubt, very trifling, but we suggest that a correction should be made in the second edition which the book deserves.

THE DECORATION AND RENOVATION OF THE HOME. By Arthur Seymour Jennings. London: W. R. Howell & Co.; New York: Spon & Chamberlain. £2 2*s*.

In the world of decoration, probable no name is better known than Arthur Seymour Jennings. He is the Editor of the *Decorator*; he has written a number of text books on painting and decorating, and he is consulting examiner in House Painting and Decoration to the City

and Guilds of London Institute. It goes without saying, then, that when he writes on the practical side of his subject, all the information that he gives us is thoroughly sound and valuable. And the present volume contains a great deal of such information dealing with all branches of house painting and decoration, particularly in connexion with the renovation of old houses. As one who has recently had trouble with painters in his own house, the writer of this note turned with special interest to Chapter IV., where Mr. Seymour discusses the preliminary stages of painting, such as cleaning and rubbing down. He found the instructions given there most thorough and admirable, and he would like to see them placed in the hands of every painter, where they are very badly needed, for at the present day—unless his experience is peculiarly unfortunate—there is a most unfortunate tendency to scamp the preliminary work, with the result that the paint soon cracks and blisters and looks disreputable.

Many suggestions are given as to schemes of decoration suitable for different rooms and for different purposes. As Mr. Jennings remarks, it would be too much to expect that every one of these selections will be approved by all readers. Personally, we do not much like the colour schemes for front doors, which form the frontispiece of the volume, nor do we care for the illustrations of the Chippendale dining room or the Adam drawing room. Whilst, however, it is useless to hope for agreement on details of taste there are certain general principles recognised by people of culture, and these are clearly set forth by Mr. Jennings. The book is to be very cordially recommended to all interested in house decoration, which ought to mean, though we are afraid it does not, to all who live in houses.

GENERAL NOTES.

Foundries and Craftsmanship.—At the twentieth annual conference of the Institution of British Foundrymen held on June 13th, the Oliver Stubbs Gold Medal was awarded to Mr. W. Sherburn for an interesting and thoughtful paper on "The Evolution of the Foundryman," read by him before the Lancashire Branch of the Institution. Amongst the many points dealt with was foundry training, in connexion with which the author urged the desirability of attempting to recover the "link of human fellowship" associated with the old apprenticeship system in the earlier half of the 19th century. He contends that our methods of elementary education have, until very recently, been hopelessly wrong and wasteful. "Many a promising craftsman has been spoiled by being kept too long at school and many a seemingly unlikely lad has grown skilful because he was obliged to begin work early." At the same time, he admits that "the transfer of boys from the free life and short hours of school to the discipline and sometimes drudgery, of the workshop is often too violent." He recalls James Nasmyth's views on this subject: "While he (Nasmyth) had a few premium apprentices (more to please friends than himself), he . . . . greatly preferred to employ intelligent young sons of workmen under a quite free arrangement." They were encouraged to make progress and were advanced in work and wages accordingly. "For most boys of 14 years of age, it can be stated that the workshop is a better place of education than the day school." The result of the author's reflections on the problem he so carefully considers in his paper is, he says, that every individual industrial concern ought to be "a complete organism or an enlarged family." The spirit which has rendered laborious and uncomfortable work attractive "can do the same in the larger combination if entered into with the same goodwill and mutual respect." He adds: "We"—that is, employers and employees—"are all in the same boat, a truism in war-time is not an atom less true of our craft to-day. That an increasing number of our captains of industry realise this fact and are using their influence in the right direction is as hopeful as it is true."

Candelilla Wax in Mexico.—Since the close of the World War, the production of candelilla wax in Mexico has shown little life, but reports have recently been current, writes the United States Consul at Saltillo, of a revival of interest in this product. In former years, practically the entire output went to Germany, and Europe has continued to be the best market for this commodity. In 1917, a considerable amount was shipped to the United States, and was found to be very satisfactory. The cost of the local product has advanced about 25 per cent. over pre-war prices, labour and other incidental costs having increased. From two to five years, according to the amount of rainfall, are required for the production of the candelilla weed, from which the wax is obtained. Primitive methods are still employed in Mexico, the present yield of wax being only about two per cent. of the weed employed, but it is expected that improved methods will soon be perfected whereby three per cent. of pure wax, together with about two per cent. of valuable resins, will be obtained.

Radium Production in Belgium.—Large works are in course of erection at Colen in the Province of Limburg, for the treatment of radio-active minerals which can be supplied in abundance by the Belgian Congo. According to a report by Mr. J. Picton Bagge, Commercial Secretary to H.M. Embassy, at Brussels, the first division for treatment of the metals is already at work, and it is hoped very shortly to produce the first gramme of radium.

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FRIDAY, JULY 20, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2

FUND FOR PURCHASING AND RENOVATING THE SOCIETY'S HOUSE.

EIGHTH LIST.*

	£	s.	d.
Amount previously acknowledged	42,967	13	4
Sir Edward Davson ..	26	5	0
Alexander James Anderson, Esq., C.S.I.	10	0	0
G. K. Menzies, Esq. ..	10	0	0
Thomas B. Mackenzie, Esq., M.I.Mech.E.	5	5	0
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Percy Hamilton McKay, Esq.	1	1	0
	43,033	17	4

The above list includes all subscriptions received up to July 14th. Further lists will be published in the *Journal* from time to time.

Fellows of the Society are reminded that the amount aimed at by the Council is £50,000, which will cover the cost of renovating and decorating the House.

*The Seven former lists were published in the *Journals* of December 2nd, 1921, January 13th, February 24th, May 5th, July 14th, and November 17th, 1922, and February 9th, 1923.

NOTICE.

PRESENTATION OF THE SOCIETY'S ALBERT MEDAL TO SIR DAVID BRUCE AND SIR RONALD ROSS.

The Council of the Royal Society of Arts attended at Clarence House, St. James's, on July 13th, when HIS ROYAL HIGHNESS, THE DUKE OF CONNAUGHT AND STRATHEARN, K.G., President of the Society, presented the Society's Albert Medal for the present year in duplicate to MAJOR-GENERAL SIR DAVID BRUCE, K.C.B., D.Sc., LL.D., F.R.C.P., F.R.S., and COLONEL SIR RONALD ROSS, K.C.B., K.C.M.G., D.Sc., LL.D., M.D., F.R.C.S., F.R.S., "in recognition of the eminent services they have rendered to the Economic Development of the World by their achievements in Biological Research and the Study of Tropical Diseases."

THE DUKE OF CONNAUGHT was attended by LIEUT.-COLONEL SIR MALCOLM MURRAY, K.C.V.O., C.B., C.I.E.

The following members of the Council were present :—

Lord Askwith, K.C.B., K.C., D.C.L. (Chairman), Sir Thomas J. Bennett, C.I.E., M.P., Sir Dugald Clerk, K.B.E., F.R.S., Mr. Edward Dent, Sir Robert A. Hadfield, Bt., D.Sc., F.R.S., Sir Thomas Holland, K.C.S.I., K.C.I.E., F.R.S., Dr. William Henry Maw, M.Inst.C.E., Lt.-Col. Sir A. Henry McMahon, G.C.M.G., G.C.V.O., K.C.I.E., C.S.I., Sir George Sutton, Bt., Mr. Alan A. Campbell Swinton, F.R.S., Dr. J. Augustus Voelcker, Sir Alfred Yarrow, Bt., M.Inst.C.E., with Mr. G. K. Menzies (Secretary of the Society), and Mr. S. Digby, C.I.E. (Secretary of the Indian and Dominions and Colonies Sections).

PROCEEDINGS OF THE SOCIETY.

TWENTY FIRST ORDINARY MEETING.

WEDNESDAY, MAY 16TH, 1923.

SIR MALCOLM DELEVINGNE, K.C.B., Assistant Under Secretary of State, Home Office, in the Chair.

INDUSTRIAL LIGHTING AND THE PREVENTION OF ACCIDENTS.

By LEON GASTER, F.J.I.,

Editor of *The Illuminating Engineer*.

INTRODUCTION.

It is almost exactly three years since the writer had the pleasure of reading a paper before the Royal Society of Arts on Industrial Lighting. Rather more than seven years earlier he also dealt with the subject

from a somewhat different aspect. On this occasion it is proposed to consider the lighting of factories mainly in relation to the *prevention of industrial accidents*, in their broadest sense. But since, in the earlier papers, little was said about *illuminants* it may be well to recall briefly some of the advances of recent years.

The most noteworthy development in electric lighting, as compared with conditions prevailing before the war, has doubtless been the introduction of the gas-filled lamp. While operating at an efficiency, for the larger types, about twice that of the vacuum tungsten lamp, the gas-filled lamps have the material advantage of allowing much higher candlepowers to be attained. This circumstance has led to a much more general adoption of overhead lighting, although there are still many industrial processes where well shaded local lamps placed near to the work are useful and even essential. Improvements in gas lighting have applied mainly to low pressure lamps, a feature being the improved efficiency of the superheated inverted burners and the use of clusters of small or medium type mantles, whereby the cost of maintenance has been much reduced.

These advances have related to *intensity of light*. In "artificial daylight" units we have an instance of developments affecting *colour*. The light from an artificial source is corrected by transmission through suitably tinted glass plates, or by reflection off special coloured surfaces, so designed that the emerging light resembles daylight very closely in its effect on coloured objects. Various lighting units of this kind, such as the Sheringham Daylight and the units equipped with special Chance's glass devised by Mr. F. E. Lamplough, have recently been exhibited at meetings of the Illuminating Engineering Society. Artificial daylight is of obvious importance to industries concerned with accurate colour-matching, such as the dyeing and textile trades and the loss of light occasioned by the correction of the light is not of great moment in comparison with the advantage of being able to match colours by day or night, independent of climatic conditions. For many of the less exacting applications, for example, in drapers' shops and stores, the existing units have proved useful, and some types are stated to have even proved of value to dyers, who are very exacting in their requirements. But some appliances furnish light that can only be considered an approximation to average daylight, and it is essential that we should have some sceintific means of specifying and determining the accuracy with which daylight is imitated. A contribution bearing on this aspect is to be presented at the forthcoming annual meeting of the Illuminating Engineering Society.

Advances in the design of reflectors, especially for industrial lighting, have also been of considerable importance both in enabling light to be distributed more efficiently on the work and in screening the source of light from the eye and avoiding glare.

Another useful advance has been the simplification and development of instruments for measuring illumination, which have proved of great value in making measurements in factories and ascertaining the illumination customary for various processes. I propose to deal with some of these advances in a later section of the paper, when considering how compliance with recommendations on industrial lighting in practice can best be ensured.

Industrial Lighting and Accidents.

After this brief introduction let us now turn to the relation between industrial lighting and accidents. On the occasion of my last paper before the Royal Society of Arts in 1920, I recalled the evidence on this point afforded in the First Interim Report of the Departmental Committee on Lighting in Factories and Workshops issued in 1915. It was shown that accidents occurred most frequently during the dark winter months and that in almost all the industries studied the accident rate by night was considerably higher than that by day; the average increase for all industries was 29% for all forms of accidents, and as much as 71% for persons falling. In the case of docks, where this type of accident is frequent, the increase was 102%.

These, it may be noted, are reported accidents occasioning bodily injury. The annual report of the Chief Inspector of Factories for 1920 shows that reported accidents in that year were 1,404 fatal and 137,298 non-fatal, and it is estimated that nearly £6,000,000 was paid in this country for accident compensation under the Workmen's Compensation Act. These figures are sufficiently striking. But the total number of accidents occasioning some degree

of bodily injury must be far greater than this. In the first place the above figure does not include accidents on railways or in mines, which come under a separate schedule. Next it is admitted that many more or less serious accidents are not notified to inspectors owing to neglect or evasion. Further there are many unreported minor accidents, which may involve only trivial bodily injury, but, nevertheless, do cause a heavy loss of production. Mr. D. R. Wilson, in an instructive contribution to "Safety First" (the Bulletin issued by the British Industrial Safety First Association) mentions that in certain munitions factories the proportion of minor to major accidents was as high as 30 : 1, and whilst this is probably a higher ratio than would be found in most industries, the general ratio is probably at least 10 to 1. There would thus be something like 1,400,000 minor accidents each year, all causing some disturbance in factory routine and loss of production. If one assumes that each minor accident involves absence from work of half a day the number of working days lost annually through this type of accident alone amounts to 700,000. Mr. Wilson also points out that the productive capacity of a worker, even if he remains at work, may also be temporarily reduced. Thus even quite trivial accidents may and do cause a heavy loss in production.

Mr. Gerald Bellhouse, H.M. Chief Inspector of Factories, has remarked that of accidents reported to inspectors, approximately two-thirds are not due to machinery at all, and of the remainder only a third can be ascribed to absence of guards. Predisposing causes of accidents are broadly classified by Mr. Wilson as (*a*) those due to the work, including such causes as fatigue, rate of output, etc., (*b*) those due to the conditions under which the work is done, *e.g.*, lighting and temperature, and (*c*) those due to the personality of the worker. The great value of the beneficent supervision of the Home Office in factory work is generally recognised. But there are many accidents due to acts and faults of individuals whether worker or employer, which cannot be dealt with by Act of Parliament, but only by processes of education. It has been claimed in the United States that 75% of accidents are preventable and the work of the "Safety First" movement, both in America and in this country must by now be familiar to everyone. The results attending the work of the British Industrial "Safety First" Association show beyond question the benefit of such methods. In many cases reductions of 21 to 76% have been effected in periods of one to three and a half years by firms who have adopted "safety first" methods.

The B.I.S.F.A. has recently devoted special attention to the classification of accidents and in a recent contribution to "Safety First" the writer suggested methods by which data could be collected on a uniform basis, showing the relation between inadequate lighting and accidents. While I do not wish to create the impression that bad lighting is the *only*, or even the chief cause of accidents, it is nevertheless an extremely important item, both in relation to safety and as affecting health and efficiency in workshops. To take an extreme example we have only to consider what happens when there is a failure in the supply, and the shop is in darkness. All work is immediately brought to a stop.

If we next imagine that there is lighting available, but of a very inadequate nature, we can still understand that the worker can only perform a fraction of the work that he would do in the same time with good illumination. His progress will be slow and his execution of work faulty. If there is moving machinery near he will probably be oppressed by the consciousness that he must exercise care to avoid an accident. He will, in short, lack the *confidence* that is given by good lighting conditions. As an illustration of how bad lighting, by interfering with some critical process, may cause danger, we may take the water-gauge of a boiler. If the light is insufficient for the level of the water to be seen clearly it is highly probable that sooner or later an accident will occur.

There are many processes where insufficient or badly arranged lighting is obviously a direct source of danger. Such appliances as band knives, circular saws, guillotine presses, drills, etc., where the worker must with his fingers guide the material into position, need particularly careful lighting, both as regards intensity of light and absence of troublesome shadows, which are both dangerous to the worker and liable to cause spoilage of material. It is clear that even if the worker escapes injury in such cases, he will be hampered by constant apprehension, which must slow down his efforts and prevents the

feeling of confidence referred to above as an essential to good work.

This feeling of confidence should extend to the general lighting of the factory. Management and workers alike should feel that the possibility of a failure of light is reduced to an absolute minimum. In cases where such a failure would be a source of danger, as for instance, in shops where workers are tending running machinery or cutting appliances, the provision of alternative systems of lighting to prevent complete absence of light should be regarded as essential. It may be noted that in cinemas, theatres and other buildings licensed by the L.C.C., special attention is invariably paid to the lighting of exits and the provision of duplicate supplies as a safeguard against panic. Similar measures should apply to factories where failure of light may cause danger. In some of the large printing works it is customary to have duplicate services for driving machinery. Continuity of lighting, which is equally important, can be secured in various ways.

Inadequate Lighting as a cause of Industrial Fatigue.

One finds also in practice that the same causes that result in accidents involving bodily injury or prejudice to health, are almost invariably also responsible for damage to material, spoiled work and mistakes, for which the worker may be blamed, but for which he is often not strictly responsible.

I suggest, therefore, that all unfortunate occurrences of this kind might be conveniently grouped together and studied conjointly, and it will be seen that inadequate lighting plays an important part in the causation of all these various "accidents." This is admirably shown in a recent report on the "Study of Accident Causation" issued by the Industrial Fatigue Research Board, a body which has done a considerable amount of very valuable research on industrial operations.

One important conclusion derived from a study of conditions in munitions works during the war was that personal susceptibility plays an important part in accident causation. In an industry demanding keen sight the number of accidents might be materially reduced if one could select those workers whose eyesight is sufficiently good. Self-protection on the part of a worker from a potential danger is often dependent upon rapidity of vision and this in turn is affected by the nature of the lighting at the time. Inadequate or unsuitable lighting has, in fact, been shown to be an important contributing cause of accidents.

In considering the effects of inadequate lighting one naturally thinks first of its effect on the eye. It is evident that the first effect must be to increase the strain on the eyes, and this may lead to the developments of defects of vision. Statistics published by the Departmental Committee on the Welfare of the Blind indicate that one person in 1,274 of the whole population of these isles is blind, and more than 30% of the blind population are in receipt of Poor Law Relief. A very much larger proportion of our people is more or less handicapped by defective vision, and this handicap is a manifest economic loss.

But the effect does not stop here. The result of difficulty in seeing is to accentuate the whole effort of the human organism and accelerate industrial fatigue, rendering the worker less alert, less able to do his work efficiently and much more liable to accident. It has frequently been noted that the hours when workers are most fatigued and can do least work are also those during which accidents are most liable to occur.

The impression that one derives from much of this recent work is that in the past too little attention has been given to the human element. In most industries there are opportunities for making small modifications in the routine of the work such as may enable them to turn out more in a shorter time and with less fatigue. Such experiments, be it noted, are not in any sense an attempt to "drive" the worker, but rather an attempt to lighten his labour, to remove unnecessary interference with his work and eliminate possible sources of danger.

The Relation Between Lighting and Output.

The influence that such changes may exert is strikingly shown in the annual report for 1922 of the National Institute of Industrial Psychology, a newly formed body which has already carried out a number of extremely suggestive and useful experiments and deserves every encouragement. Thus experiments in various factories showed how, by slight modifications in the

routine of work, increases in output varying from 10-40% were secured, a notable case being the reduction of breakages of glass and china by over 53% in the case of a large catering firm, merely by introducing methods which reduced the worry, irritation and fatigue amongst workers. Such records enable us to understand how the provision of better lighting may lead to improved output, and in several cases, notably sweet making and packing, where increases of 10-14% were recorded, better lighting was mentioned as the chief contributory factor.

Good illumination, by removing this cause of fatigue and annoyance, is a benefit to worker and employer alike. An instructive instance of the effect of light on output is afforded by a recent investigation in a coal mine, conducted by Messrs. E. Farmer, S. Adams, and A. Stephenson, and summarised in a recent issue of the Journal of the National Institute of Industrial Psychology. It was found in this investigation that, by using a lamp of four times the weight of the ordinary lamp, but affording four times as much light, an increase in output of over 14% was obtained. Experiments with methods of screening the light from the filament were also made, and it was found that this softening of the light added greatly to the comfort of the worker—a point of consequence in view of the conclusion of the Miners' Nystagmus Committee that this disease is attributable mainly to inadequate illumination. In the mining industry, again, we have an impressive illustration of the economic loss arising from prejudice to the health and safety of workers. Dr. T. L. Llewellyn, in an able paper before the Illuminating Engineering Society in February, 1920, estimated that 6,000 men had been disabled every year since 1913 from miners' nystagmus, and that the cost to the country amounted to over a million pounds a year. He also recalled that in 1913, 195,387 accidents occurred in the mining industry in Great Britain. Accidents, therefore, also occasion very heavy payments in compensation, the cost of which has increased rapidly in recent years. To these figures must be added the economic loss arising from the absence of workers from their occupation; so that the total each year runs into millions of pounds. It is now generally agreed that inadequate lighting is the main cause of miners' nystagmus, and it is also recognised by experts that a considerable proportion of accidents in mines could be prevented by better lighting.

As a final instance of an investigation showing the relation between lighting conditions and output, I may mention the experiment conducted by the Commonwealth Edison Company in Chicago in 1919. A survey was made of 93 factories, totalling 17,400 employees. Observations of the existing methods of lighting were first made. All defects were then remedied and modern and efficient conditions substituted. A number of factories consented to a test during a month under the new conditions, measurements of illumination and records of output being taken simultaneously; the old conditions were then restored and another test made for a subsequent month; finally, the improved lighting was again substituted and a confirmatory month's test undertaken. Remarkable results were reported. In one case the improved illumination resulted in outputs which increased by 8-27%.

The question of avoiding mistakes and spoiled work is, however, often even more important to a manufacturer than increased output. Serious damage to the reputation of a firm may be caused by the issue of defective or improperly made goods. It is common knowledge that during the war contractors supplying materials or appliances for the forces were subjected to strict limitations in this respect. If the faulty material exceeded a certain proportion the work was rejected; and in some cases where accuracy was of prime importance firms who offended in this way were liable to be struck off the official list.

All these facts are becoming more generally appreciated and there has been a material improvement in industrial lighting during recent years. One of the chief tendencies has been the provision of high general illuminations in place of individual "drop-lights," and in many factories it is now usual to find values up to 8-10 foot-candles, far exceeding those customary in the past. In such cases employers and workers unite in agreement on the greater comfort and ease of working, and it is significant that when improved lighting is once introduced no one is ever content to return to the old conditions. I would like to remark, however, that good lighting is not only a matter of providing sufficient numerical values of illumination. It is essential that other

conditions, such as absence of glare and freedom from troublesome shadows, are also complied with.

Other special circumstances to be considered arise from the nature of the surface illuminated. Thus, if the material worked with is very dark, reflecting little light, the illumination must be correspondingly increased so as to ensure a certain *brightness* of the surface. This was brought out very clearly in some experiments made by the National Physical Laboratory in connection with the first report of the Home Office Departmental Committee, the conclusion drawn being that the product of the coefficient of reflection of the material and the intensity of illumination provided should be a constant, depending on the nature of the work done.

Shininess of the surface must likewise be considered. In dealing with highly glazed and polished surfaces the lights must be so shaded and placed as to avoid direct reflection of light into the eyes—a form of "glare" which may be highly inconvenient to the workers.

Home Office Recommendations on Factory Lighting.

These and other points were clearly dealt with in the First Report of the Home Office Departmental Committee on Lighting in Factories and Workshops, issued in 1915. (Blue Book, cd. 8,000.) They have been still more clearly indicated in two subsequent reports of the Committee, issued in 1921 and 1922. The first of these supplementary reports is concerned mainly with the avoidance of glare. The clause relating to this point is as follows :—

"Every light source (except one of low brightness) within a distance of 100ft. from any person shall be so shaded from such person that no part of the filament or mantle or flame is distinguishable through the shade unless it be so placed that the angle between the line from the eye to an unshaded part of the source and a horizontal plane is not less than 20°, or in the case of any person employed at a distance of 6ft. or less from the source not less than 30°."

I propose to show some diagrams illustrating the methods of complying with this requirement, which should not prove difficult to fulfil by the aid of modern lighting appliances. In particular it may be noted that if scientifically designed reflectors are used with lamps for which they are intended, so that the filament falls well above the rim of the reflector, the procedure can be greatly simplified. Many forms of industrial lighting units of this kind could be used in any position in a factory without infringing this recommendation. A source whose brightness is less than 5 c.p. per sq. inch, or a source equipped with a suitable translucent shade rendering the filament or mantle indistinguishable, would fall outside the limitation in regard to angle and could be used in any position. But it should be remembered that the covering of a brilliant source by a very small shade (such as a silica cup covering a high pressure gas mantle or a small opal globe surrounding a high power electric source) may give this shade or globe a brightness more than three or four times as great as the five candles per square inch, so that it may cause considerable glare, in which case it should be treated as a source of light in itself.

This report also contains general recommendations that "adequate means shall be taken to prevent the formation of shadows which interfere with the safety or efficiency of any person present," and that "no light sources which flicker or undergo abrupt changes in candle power in such a way as to interfere with the safety or efficiency of any person employed shall be used for the illumination of a factory or workshop."

The third report, issued in September, 1922, is concerned mainly with "working illumination." It will be recalled that the first report specified certain values of illumination, easily complied with, as minima desirable in the interests of safety and general convenience. This moderate general illumination (0.25 foot-candles in factories and 0.4 foot-candles in foundries) was recommended irrespective of the actual working illumination. After very careful consideration the Committee has wisely determined that further experiments are needed before minima for working illumination can be prescribed. For the present a schedule of operations divided into two classes (fine work requiring 3 foot-candles and very fine work requiring 5 foot-candles) is presented, as an indication of modern practice. It is recommended that further tests of the conditions of illumination requisite should be made with the co-operation of the industries concerned—a method which will, doubtless, meet with general approval. There can be no question of the importance of obtaining the help of

those actually engaged in the industry and a completely satisfactory solution of industrial lighting problems is only possible with their co-operation.

The very comprehensive schedule accompanying the Home Office Committee's Third Report, dividing industrial operations into "fine" and "very fine" processes, is tentatively suggested as an indication of minima in good modern practice; but there are many factories where the management, recognising the benefits of good illumination, may decide to provide a considerably higher illumination for certain processes. As an instance, I may mention some data recently presented before the Illuminating Engineering Society on the lighting of compositors' frames in newspaper offices. In some modern works as much as 10-12 foot-candles is to be found.

Instruments for Measuring Illumination.

Having thus referred to the values of illumination that are becoming recognised as desirable for various industrial processes, it may be of service to add a few words on methods of measurement. There are now quite a number of illumination-photometers available, by the aid of which the illumination at any place in a factory can be readily measured.

Several new instruments have been developed both in this country and in the United States, and Bechstein has recently described a new form of instrument developed in Germany, which embodies many of the features of modern British and American types. The tendency of design is in two main directions, simplification and greater accuracy. Whereas these instruments were originally regarded as mainly intended for the expert, efforts are now being made to develop apparatus which even a person with little knowledge of photometry can soon learn to use—in particular the idea of providing a scale on which the illumination can be read off by inspection, with little or no manipulation of the instrument to obtain balance.

We also note a general recognition that a modern instrument should be equipped with an ammeter or voltmeter, in order to enable the user to be sure that the voltage of the cell supplying current to the small lamp within the instrument has not altered; and preferably also a rheostat to enable the current to be readjusted to the correct value. Such accessory appliances are very conveniently assembled in the ingenious photometer devised by Dr. Tuck in the United States, and they are likewise provided in the new Bechstein photometer, mentioned above; in several respects the latter instrument shows the influence of English and American design, being more portable and less cumbrous and elaborate than some of the older German types. There is no doubt that such instruments are steadily improving and much useful information has been gained with them. But further research might still be usefully expended in this field, especially in providing means to ensure that the user can (*a*) recognise when the voltage of the battery has fallen, rendering the reading inaccurate; (*b*) compensate for this change either by adjusting the position of the lamp or by diminishing the resistance in the circuit; (*c*) detect in good time when the battery is beginning to run down and charging is necessary. With several modern types of instruments one may expect, with reasonable care, an accuracy of about 10-15 per cent., which amply suffices for most practical requirements. The greatest inconvenience at present, to non-technical people, is the battery, and I would like to throw out as a useful subject for research the possibility of designing a very simple instrument based on observation of the illumination at which a small pattern becomes indistinguishable, or comparison of the illumination with some radio-self-luminous substance, which might answer requirements in cases where great accuracy is not important, but it is desired to gain a general idea of the order of illumination prevailing. Notable improvements have also been made in the various instruments devised by Dr. Clayton Sharp and Mr. P. S. Millar in the United States, both as regards simplicity and accuracy. Much research has been done on "physical photometers," *i.e.*, instruments based on the action of light on a photo-electric cell. Selenium cells have long ago been proposed for this purpose, but there are certain difficulties, as regards the inertia and variable sensitiveness of the substance, not yet overcome. Another form of photo-electric cell, utilising the response to light of certain alkali metals (potassium, rubidium, barium, etc.) has given promising results in the laboratory as an almost exact proportionality between current and intensity of light is said to be

obtained. It is conceivable that these experiments may ultimately lead to a direct reading photometer, the value in foot-candles being indicated by a pointer on the dial of a galvanometer, when the instrument is presented to the light. The instrument would have to be carefully calibrated in the photometric laboratory, but the user in practice would be relieved of the process of determining when two surfaces are equally bright. A reliable apparatus of this kind might serve other uses, *e.g.*, in automatically giving a warning when daylight has fallen to a prescribed value and artificial light is needed. In view of the attention now being devoted to glare a very simple apparatus, possibly based on diminishing the brightness of a source until some pattern becomes indistinguishable, would be useful to determine when the brightness in candle power per square inch exceeds a prescribed value.

Daylight Illumination.

Photometric measurements, which have proved so valuable in the study of artificial illumination, have also been applied with good results to tests of natural lighting during recent years. When one considers that probably three-quarters of the work done in factories in this country is performed in daylight the need for the study of daylight conditions is obvious. The design of a modern factory is, indeed, largely governed by considerations of maximum admission of daylight. Daylight varies enormously in intensity at different times of the year and at various periods of the day and these variations have been mapped out by systematic photometric measurements so that one can predict the *average* value that may be expected at any time. Naturally, special circumstances, such as fogs, etc., may lead to exceptionally low values, and it might at first sight appear that daylight is so variable and uncontrollable that measurements are of little value. Nevertheless, such measurements have proved in practice useful in various ways. In the first place these measurements have given us a much better insight into conditions of natural illumination, and enable us to appreciate better conditions in artificial lighting which are less perfect than those prevailing by day. A most significant result has been obtained in a series of investigations conducted for the Industrial Fatigue Research Board in the silk-weaving, fine linen weaving and cotton weaving industries. In these three cases it was shown that the average output by artificial light was respectively 10%, 11% and 5% less than by daylight. Evidently, therefore, the conditions of artificial lighting were less perfect than those prevailing during the day, and imposed a distinct handicap on the worker. The exact nature of these imperfections requires further study. It may possibly be found that the much lower value of illumination derived from artificial light, as compared with daylight, is responsible; or it may be that the diffusion of light is less satisfactory, giving rise to inconvenient shadows. These researches are quoted as an authoritative indication of the direct relation between good illumination and output, and as an instance of the useful results to be derived from the study of natural light.

Next it is to be observed that while *absolute* measurements of daylight illumination may be somewhat difficult to interpret, owing to its extreme variability, *relative* measurements, connecting the illumination on the worst lighted place in a room with the total unrestricted daylight illumination out-of-doors (the "daylight-factor") have a very direct value in dealing with access of light into buildings. Much work has been done on these lines during recent years. Valuable and frequently quoted conclusions were set out in the report of the Joint Committee of the Illuminating Engineering Society on the Natural Lighting of Schools in 1914. Among other recommendations it was suggested that windows should be so designed that the darkest desk in a schoolroom should not receive less than 0.5% of the unrestricted illumination from the complete sky-hemisphere. Useful work is also being done at the National Physical Laboratory where a special experimental building for the study of daylight illumination has been erected. Architects and others could, doubtless, obtain much useful guidance by making use of the facilities which the laboratory affords for predeterminations of daylight-access in new buildings.

Many measurements of daylight have been recorded in the reports of the Home Office Departmental Committee on Lighting in Factories and Workshops. A useful review of the whole subject was also given in a paper by Messrs. P. J. Waldram and J. M. Waldram before the Illuminating Engineer-

ing Society this year. The illumination derived from a complete hemisphere of sky out of doors may attain very high values, exceeding 5,000 foot-candles, and direct sunlight illumination is still more intense. Mr. Waldram has found that people in offices are apt to complain of insufficient light when the illumination on the works is less than 0.2% of the value derived from an unobstructed hemisphere of uniform sky, which under the best conditions would mean an actual illumination of about 10 foot-candles, but as a rule considerably less. We may safely assume that the daylight illumination in an office should not be less than that considered necessary by artificial light, say, about three to four foot-candles; indeed, owing to the fact that the eye is adapted to a higher order of illumination by daylight, it usually requires more. Thus, in some American codes it has been laid down as a general principle that natural illumination for a process should be *twice* that recognised as desirable by artificial light.

A question that deserves some study is the treatment of the twilight period, when daylight is failing and artificial light is about to be substituted. It is possible that the demands of the eye are accentuated by the fact of one's consciousness that the daylight is becoming progressively less. One finds that people sometimes desire the substitution of artificial light when the actual value of daylight illumination in foot-candles is still fairly high. In practice a mixture of natural and artificial light is usually regarded as objectionable; possibly the transition period might be dealt with by the use of artificial daylight units. It has also been observed that whenever a change from daylight to artificial light, or vice versa, is made, the output of workers in a factory is temporarily diminished. This one would naturally expect in view of the fact that the eye has to accommodate itself to the new conditions.

Measurements of daylight have proved extremely valuable in connection with ancient light cases. A significant tribute to their value was paid by the judge in a recent case of this kind in Bradford, where the record of tests made by Mr. Waldram had a material influence in determining the decision. The more difficult problem of *predicting* conditions of natural lighting in buildings prior to erection is now receiving attention and distinct progress has been made.

There is, however, one factor which considerably affects all predictions of daylight illumination in buildings,—the condition of the glass. When a factory has a very large window area cleaning may become an expensive item. But the encrustation of windows with dirt, which materially diminish the daylight available, should be avoided and in general a manufacturer will find that regular cleaning is fully compensated by the gain in illumination. Some measurements of the loss in light have been made. At a recent meeting of the Illuminating Engineering Society specimens of glass were shown absorbing from 25 to 60% of light, according to the amount of dirt. Windows surely ought not to become so dirty that more than half the light striking them is absorbed, but it would be useful to manufacturers to receive some guidance as to the circumstances in which cleaning has become imperative. This might be framed as a limit to the percentage of light absorbed by the glass, or the limiting reduction in the value of the "daylight factor" indicating the degree of access of light into the building.

In the case of artificial lighting appliances the need for periodical cleaning and maintenance is, if anything even more important than in the case of windows, for one is working with a much lower order of illumination than by daylight, and the effect of a diminution of light owing to absorption is of greater moment. Tests have shown that a few weeks of neglect of lamps and fittings in factories may lead to a diminution of 30%; in planning installations it is therefore wise to allow a margin above the estimated value of illumination, so as to allow for deterioration.

Ideal Requirements and Practical Solutions.

Wherever the conditions of lighting have been carefully studied the tendency during recent years has been to advocate a generous value of illumination, the cost of which is almost invariably small in comparison with the wages of operators. (In a number of large factories which have recently come under the writer's notice the proportion was only 1%). A striking instance of this tendency to recommend higher values of illumination is to be seen in the account of a survey of lighting conditions in post-offices, made by the Office of Industrial Hygiene of the United States Public Health Service at the request of the Postmaster

General.* It was found that the higher the illumination, up to a certain point, the more rapidly was the work performed. Those having normal vision worked most rapidly under an illumination of between 8 and 10 foot-candles; those with eye defects showed less fatigue when working under higher intensities than when working under lower intensities. The provision of 10 foot-candles on the working plane would, according to the methods suggested, require about 2 watts per sq. foot of floor area. Great importance is attached to avoidance of glare and the specification of the glassware for use in post-offices is directed to securing a brightness of not more than 2 c.p. per sq. inch in the lighting fittings.

This report is mentioned in order to show that the requirements in the Home Office Departmental Committee's reports, while intended to remedy cases in which lighting is clearly inadequate, are quite moderate in view of conditions to be found in some modern installations. From my experience I am satisfied that the conditions can be readily met by the aid of modern appliances and methods. Through the courtesy of Mr. G. J. Shave, Chief Engineer of the London General Omnibus Company, I was recently afforded an opportunity of inspecting the lighting arrangements at the company's new built repair works at Chiswick, which have been the subject of great care and special experiment. Mr. Leese, the engineer in charge, strongly endorsed the value of good illumination in such a work as this, which is of special interest in view of the great variety of process, wood-working, rough and fine metal work, painting and all manner of repair operations, carried out on such a large scale. The works afford an instance of general lighting from well-screened overhead lights, supplemented by special local illumination, up to 25 ft. c., at points where very accurate work has to be done. I hope to show a few illustrations of the methods employed, which deserve careful study.

I may conclude this paper by a brief survey of some recent developments in the form of codes, recommendations and other investigations abroad on industrial lighting. In all such investigations our natural course is *firstly* to form some conception of what constitutes ideal factory lighting, *secondly* to see how far such conditions can at present be obtained in practice. Ideal industrial lighting can be only broadly defined. It should enable work to proceed by night with the same ease and convenience and safety to workers as exist under the best daylight conditions; indeed in view of the very variable nature of daylight one might hope to obtain better conditions in some cases.

General experience, aptly summarised, in reports of the Home Office Departmental Committee, indicates that for ideal requirements there are three main conditions to be satisfied:—(a) sufficient illumination, (b) constancy and uniformity of illumination over the working area, (c) the placing and shading of lights so as to avoid inconvenient extraneous shadows on the work. There will also be special conditions to be fulfilled arising from the peculiar nature of any industrial process.

It will naturally take some time before such conditions are completely understood for all industries. The best course is, doubtless, to group together certain industries having broadly similar requirements, to study them in detail, and to see how far the experience so gained applies in other cases. Hence the Home Office Departmental Committee acted wisely in first concentrating attention on the engineering, clothing and textile industries.

Legislative measures require very careful consideration. One might justly hesitate to legislate on many matters in which *recommendations* can confidently be made. The aim should be to prevent any serious abuse of light, and yet impose no hardship on the manufacturer. If too exact and detailed, a code becomes difficult to enforce without becoming a source of annoyance; if too vaguely worded its interpretation may give rise to differences of opinion. An ideal measure is one which employers and workers readily accept as being made in their joint interests. Educational propaganda is extremely desirable in order to make the aims of official reports generally understood and the nature of their recommendations familiar. The discussions on industrial lighting before the Illuminating Engineering Society have, no doubt, proved most beneficial in this respect, and the opportunities which the Royal Society of Arts has afforded from time to time for the explanations of these matters has also been extremely helpful.

* Elec. World, March 24, 1923.

Experience in the United States, where codes of industrial lighting are now in use in seven different States, has been broadly similar to our own, and the "codes", although somewhat more detailed, are based on principles similar to those adopted by the Home Office Committee. Some general recommendations have also been made by the Illuminating Engineering Society in Germany, and I learn with pleasure that a Committee working under the Minister of Labour in France is now devoting attention to industrial lighting. It may be noted that a Committee was formed by the French Government in 1912 in order to study these problems, but the work was unavoidably interrupted by the war.

Another instance of the spread of interest in the subject is afforded by the work of the International Labour Bureau of the League of Nations at Geneva. Dr. L. Carrozi, who is associated with this department, has in preparation a comprehensive report on industrial lighting, which will be awaited with keen interest. I may say that this department has collected much evidence on other points of considerable interest to those concerned with factory management, such as the beneficial results of periodical rests, enabling the worker to recuperate and lessen industrial fatigue, and the careful selection of those entering various trades with a view to ensuring that their physique and general health is such as to enable them to do the work efficiently and without ultimate prejudice to their well-being. Naturally, this last point is of special consequence in those industries which impose a somewhat severe strain on the eyes, and where defective vision would be a great handicap and hardship to the worker.

During recent discussions before the Illuminating Engineering Society we have dealt with a number of special aspects of industrial lighting; the discussion on the Lighting of Printing Works, which took place in this room only a few weeks ago, is a typical example. We were fortunate in receiving the co-operation of representatives of the Joint Industrial Council of the Printing and Allied Trades of the United Kingdom, and it was evident that many of the problems presented, such as the lighting of compositors' frames, could only be properly solved by exchange of views between lighting experts and those practically conversant with the processes to be illuminated. Our experience in other discussions has been the same. There is an ever-widening field for experiment and research, and it is to be noted that most of these problems cannot be solved by exchange of experience alone, but require a certain amount of experiment. As an example of such researches I may recall the tests made at the National Physical Laboratory in connection with the researches of the Home Office Committee, workers being asked to state when the illumination was sufficient and corresponding measurements made. I am glad to say that the National Physical Laboratory has since done useful service in connection with other lighting problems, but the opportunities for research are beyond the resources of any one institution. The Department of Scientific and Industrial Research has taken a sympathetic view of this matter, and it would be desirable that this department should, in conjunction with the Illuminating Engineering Society, initiate experiments through the various research associations with which the Department has established relations.

There are other matters which have reached a stage when they might well form the subject of international discussion, and a step in this direction was taken by the International Illumination Commission at its first Technical Congress in Paris in 1921, when an international technical sub-committee was appointed to review the question of industrial lighting. While each country has its own methods there is much "common ground" in industrial lighting, and it is conceivable that in the future these generally accepted principles will be embodied in an international code of industrial lighting.

Conclusion.

In the meantime it is a matter for gratification that the subject of industrial lighting has been studied in such a thorough and scientific manner by the authorities in this country and the judicious and sympathetic manner in which the Home Office has dealt with this complex problem should receive general recognition. In this paper I have endeavoured to give a summary of the chief conclusions conveyed in the three reports of the Departmental Committee on Lighting in Factories and Workshops, to show that their application involves no hardship to workers or employers

and that these principles should be readily accepted for their mutual benefit. I hope, therefore, that in the near future they will be embodied in the Legislation of this country relating to factories, and that light, heat and ventilation will be dealt with jointly as essentials to health, safety and efficiency of work.

In conclusion I should like to express my appreciation of the sympathy which the Royal Society of Arts, as a body concerned with the application of science to industry, has always shown towards the study of industrial illumination, and of the valuable service which the Society is rendering in again devoting its platform to the discussion of this important subject.

DISCUSSION.

THE CHAIRMAN, in opening the discussion, said two things were rather remarkable about the question of industrial lighting. One was that it had taken a hundred years of factory administration and study of industrial conditions before the subject began to receive the attention which it deserved. He said "began to receive attention," because it was ouly just beginning to receive the attention which it required. The official history of the subject in this country began with the appointment of a Home Office Committee only ten years ago. The other remarkable thing was the enormous amount of important work that had been done within those ten years. For that work the Department was indebted very largely to the distinguished Chairman of the Committee, Sir Richard Glazebrook, to Mr. Gaster, and to one or two members of the audience who were also connected with the Committee.

Mr. Gaster had ended his paper with the hope that in the near future the recommendations of the Departmental Committee would be embodied in legislation. He did not think it was any violation of official secrecy to say that, when the next Factory Bill was introduced, a clause on lighting would certainly be found in it. As the Departmental Committee had, however, pointed out, statutory provisions could not be carried very far at the present moment; they could only be expressed in more or less general terms. As the Committee had said, before anything like definite standards could be fixed for the fine and very fine classes of work, a great many more data had to be collected. The Committee had recommended that that work should be put in hand at once with a view to fixing as soon as possible such standards. The Home Office had, within the last few months, called into counsel the Joint Industrial Councils and the Trade Boards, and other joint bodies representing employers and workers in all the chief industries of the country which were concerned in the question. They had sent out a circular letter last November inviting those bodies to take up the question. It was very satisfactory to be able to record that, as a result of that circular, and as a result of the consultations which had taken place between the Department and the joint bodies, a very great amount of interest had been developed, and a very large number of the Councils and Trade Boards concerned had signified, not only their willingness, but their great desire to take part in the work. Arrangements had already been made in many industries for the collection of the necessary data. So that the industries themselves as well as the Department had really begun to take the matter in hand.

Mr. Gaster had referred to the question of education. He thought they could not rest satisfied until something more had been done than consulting representative bodies. Something had to be done to take the subject into the factories themselves, and to persuade the individual employers and workers in the factories that the matter was one of vital concern to industry from the point of view of efficiency, economy and output, and also from the point of view of the health and comfort of the workers themselves. That could only be done by some educational process, because his experience, and he thought the experience of most others interested in the subject, was that work of that kind was most difficult. One could carry the expert and very often the representative bodies, but when one came to try to secure the interest of the great mass of the managers, the officials, the foremen and the workers in factories, one had to move a very heavy weight indeed; and one of the things that would have to engage attention, if the progress which ought to be made in the matter was going to be made, was how to secure that interest and that understanding of the importance of the subject among those classes.

MISS ROSE SQUIRE said the Chairman had mentioned the communications which had gone from the Home Office to the chief industries concerned in the lighting in connexion with the fine and very fine processes in their works. That letter had been sent, among others, to all the joint bodies of employers and employed in the industries mentioned in Appendix I. to the Third Report of the Committee, and those bodies had been invited to discuss the matter and to invite a member of the Committee and a representative of the Home Office to attend and give information and discuss the whole subject. She had had the pleasure of attending a large number of meetings of joint organisations of employers and employed, and she had been very much struck with the great amount of interest which had been manifested in the subject by both sides. Mr. Gaster had rightly

said that there was a growing desire on the part of the workers and employers to receive information, and to co-operate in any steps that were being taken to improve lighting. There were two points which had impressed her in regard to the matter. One was the great need and importance of more propaganda and easily available information to be given to the workers and the employers in the factories bearing upon the particular industry with which they were concerned. The amount of information that could be obtained from the workers themselves as to the lighting requirements of the different processes upon which they were employed represented a mine of information which had not yet been sufficiently explored. She felt that, as the matter proceeded, information of more and more interest as to what was adequate and suitable for the different manufacturing processes would be obtained.

The other point dealt with safeguards against accidents. The Department had met with no criticisms of the schedules, as to the processes which had been defined as "fine" and "very fine"—those had been accepted in every case as being rightly stated—except in the case of the machines, and it had been very noticeable that in several trades both workers and employers objected to the placing of any machine whatsoever in the lower category or to having it omitted altogether. The consensus of opinion was that every machine demanded, for its safe and efficient working, all the light, and the best kind of light, that could be obtained.

MR. JAMES F. BUTTERWORTH said that as the author had exhibited many American illustrations among his slides, he perhaps would not object to his quoting a few concrete examples of what America had done in the question of lighting. When he stated that it had been found that more people in America were killed by falling down stairs and falling down in works owing to poor lighting than were killed by motor-cars, it would be realised what an important question lighting was. In a census that had been made recently in America into the causes of 91,000 accidents, it had been found that no less than 24% of those accidents had arisen entirely through inadequate lighting. What was wanted in this country was action by the Home Office, or some properly constituted authority, to introduce and to enforce standards of lighting for various industries. Nine or more of the American States had already codified a lighting standard for various industries. Some industries required much more light than others, but a proper code had been drawn up to which the industrialists in America had to conform, with the happiest results to all concerned.

With regard to the question of costs, which was an all-important matter, he had figures for three tests which had been made. In an iron pulley finishing shop, which was 40′ by 80′ by 13′, it had been found that by substituting 200 or 300-watt gas-filled lamps instead of the ordinary 40-watt lamp, whilst, including depreciation, the cost was 5.5% of the wages bill, the increase in output was 35%. In the heavy machine steel shop, 40′ by 58′, with a cost of 1.2%, an increase of over 10% in the production was obtained; and in the carburetter shop, 50′ by 80′, with a cost of .9%, an increase of 12% was obtained. That showed that as a mere matter of £. s. d. it was going to pay the manufacturer to go very fully into the question.

Where possible, machines should be painted white; and if workplaces, staircases and passages were limewashed, much more light would result, with consequent big increases in comfort and efficiency.

Sufficient attention was not paid to the proper placing of machinery. If one went into a big workroom one generally found the tables parallel with the wall facing the window. That was wrong. The people directly in front of the window got too much light. If the table were placed at right angles, the light would go down the table, and where one man now got the light a dozen men would get it. In the construction of factories in this country not enough glass or steel was used. In American practice to-day often from 80 to 85% of the wall space of a factory was glass and steel. It could be imagined what that meant in the increase of light and comfort to the workers and in the decrease of the cost of manufacture.

He again emphasised the necessity of some central body standardising the amount of light requisite for each trade, and the necessity for insisting upon that standard being adopted and maintained.

MR. W. E. BUSH (British Thomson-Houston Company) said it was not generally recognised that good lighting ranked far ahead of all other safety appliances. It was much better to have good lighting than machinery guards. Thousands of accidents were due to poor illumination, when they were attributed to other causes, principally to carelessness on the part of the worker. Mr. Butterworth had mentioned a survey which had been made in the United States of 91,000 accidents, from which it had been found that 24.8% were traceable to faulty illumination. It was interesting to note that that survey had been made by Mr. R. A. Simpson, of the Travellers' Insurance Company, and therefore the figure could be taken as a fair one. A similar survey had been made in 1921, and the rate had been reduced to 18.2%, which went to prove that in 11 or 12 years, owing to the improvement in lighting conditions, the accident rate had diminished greatly. It was also estimated in America that 108,000

men were lost to industry each year by accidents due to poor lighting. Poor lighting required a little more definition than low intensity. Glare was one of the principal evils that had to be contended with. Another American figure showed that in the steel industry 178% more accidents occurred during hours of darkness than in the day time. That, again, was significant. If manufacturers realised what they gained from putting in high intensity in modern lighting systems, they would not hesitate at the cost. He was afraid that too much stress was put on the humanitarian side of the question. If a manufacturer was told that if he put in good lighting he would have less accidents and would provide better conditions for his workers, and so on, it did not seem to touch his heart, but if he were told that he would thereby increase his production by 25% and earn £10,000 more a year, he would probably at once adopt the suggestion. If those who desired to see good lighting installed went about it in that way, they would accomplish their task by the back door. Very few factory executives had made the great discovery that they could increase their production by the much less expensive method of putting in good lighting then by the much more expensive method of putting in new machines. In the current number of the Transactions of the American Illuminating Engineering Society there was a very interesting article by Mr. John McGee, President of the Detroit Piston Ring Company, who had made a three years' test of the lighting in his factory, as a result of which he had increased his production by 25%. Originally he had dropped pendants and lamps with tin shades. His present intensity of lighting was 20ft. candles. Three years ago it had been 1.2. The following were the figures of the test. The first installation, after he had taken out the drop cords, had been 100-watt lamps and overhead reflectors, which had given him 6½ft. candles; and he had obtained 13% increase in his production. The next step was 150-watt lamps, which gave 9ft. candles, and an increased production over the original installation of 17.9%. The final installation was 200-watt lamps and overhead reflectors, which gave 14ft. candles, and 25.8% increase over the drop-cord installation. The increased cost of the new system over the original was 48%, which was actually 2% of the pay-roll. Those were very interesting figures, given by a man who was not in the lighting industry at all. The author had mentioned the numerous societies who were helping along the matter, but he did not mention the manufacturer of lighting equipment. It was the manufacturers of lighting equipment who were doing 99% of the development and educational work that was being carried out. Their salesmen and specialists were teaching factory executives and showing them what they needed in the way of good lighting. Every time their salesman took an order they were doing a big public duty.

Mr. P. J. Waldram said a previous speaker had advocated that the walls of factories should be made almost entirely of glass. The more glass there was in the walls of a factory, the more serious became the problem of heating and ventilation. Factories with an excessive glass area in the walls were apt to be extremely hot in summer and very expensive to warm in winter. He ventured to suggest that, purely owing to ignorance on the subject, people were rather apt at the present time unnecessarily to rush into experiments and talk about 80% or 90% of glass in the walls of factories as being a good thing. It was a very bad thing. What was wanted was for people to have a keen appreciation of what daylight really would do for them, so as to put their glass area in the best positions. In that connection he would like to suggest that Mr. Gaster had scarcely done justice to the accuracy with which daylight conditions could now be pre-determined. He had recently had occasion to investigate a building, and before going anywhere near it, he had been able, from the drawings, to predict what light he might expect to find there. When he arrived at the building and the actual light had been measured, it had been found that the light was not the same, simply because the drawings were wrong. When the drawings had been corrected there was no difference. It was very important also, that the manufacturer should not be given too much glass to clean, because, if he had an enormous area the probability was he would not clean it at all, whereas, if he had a reasonable amount there was some hope that he would clean it. In that connexion he would suggest that a regulation of a 50% loss of the amount of light was a very liberal one. A 25% loss probably meant an hour a day more artificial light, and considering what a lot the glass manufacturers had done to give a beautifully clear glass, he thought the authorities should insist upon a reasonable amount of glass cleaning. He certainly strongly suggested that glass which absorbed 25% of the light falling upon it had fallen below the limits of decency, but possibly a more lenient regulation might give better results on the whole.

The Secretary remarked thar Mr. Gaster had given him privately some very interesting particulars about a certain printing works in Italy. He was sure the meeting would be very interested if Mr. Gaster would state, very briefly, the conditions which he had found there and, more particularly, the cause which had led to those conditions.

Mr. John W. T. Walsh said it was papers such as that which had been delivered that evening which would help on the valuable work of explaining and introducing to the notice of those concerned the value of illumination from all aspects.

Mr. Leon Gaster, in reply, expressed his great appreciation of the presence of Sir Malcolm Delevingne in the chair, and the sympathetic remarks he had made in regard to the importance of good lighting in factories. He was glad to have Miss Squire's confirmation of the growing desire on the part of employers and workers to receive information on lighting. The Home Office, as he had already remarked in his paper, had for a number of years done a great deal to raise the subject of industrial lighting to a higher level, and he felt sure that their efforts to enlist the co-operation of employers and workers in dealing with the problem would have good results. Sir Malcolm had laid stress on the need for further education, and he might mention that the Illuminating Engineering Society, following a recent discussion on this subject, was arranging a joint committee which would, amongst other matters, deal with the preparation of syllabuses for instruction in illuminating engineering, and the issuing of a suitable text book.

He felt sure that the statement of the Chairman that the next Factory Act would contain a clause dealing with lighting would be generally welcomed, and that it was wisest to defer the question of detailed standards of working illumination until the industries concerned could be consulted.

He very much appreciated the concrete examples of the benefits of good illumination mentioned by Mr. J. F. Butterworth. Actual experiences of this kind were most useful. He also fully endorsed his remarks on the need for correct positions of machinery with regard to the light. But, as indicated above, he thought it would be premature to introduce too detailed codes until the best conditions for the various industries were completely determined.

He was also glad to hear from Mr. Bush, following his visit to the United States, of the growing recognition in that country of the economic value of good illumination, as a sound investment. There was no doubt that manufacturers of lighting appliances were doing valuable educational work by impressing on the public the conclusions arrived at in the discussions of the Illuminating Engineering Society, and showing how these could be complied with in practice. The co-operation of leading scientific societies and industrial concerns in such matters would be mutually beneficial.

The remarks of Mr. Menzies recalled his experiences when in 1912, he had taken part in the first Congress for the Prevention of Industrial Accidents in Milan. He had been much struck by the orderly and well devised conditions of work in some of the modern factories visited, and their excellent equipment. This applied particularly to a celebrated printing works, where everything was spotlessly clean and the arrangements for lighting, heating and ventilation were very complete, and all the latest safety devices were in use. He had also admired the construction of the building, which was imposing without being too ornate, with its impressive entrance and marble staircase.

In another factory visited, devoted to textile operations, arrangements were equally up-to-date, every precaution being taken for the prevention of accidents.

These advantages were largely due to the influence of the Italian association of manufacturers for the prevention of accidents (insurance companies), which took an interest in industrial concerns, supervising the erection of the factory from the commencement, and ensuring that all the latest labour saving and safety devices were introduced.

He had only been able to deal with a few of the chief points raised in this discussion, which contained much useful information, and formed a valuable supplement to the paper. By the references to experience in other countries, it also illustrated the fact that industrial lighting is now a subject of international interest—of common concern to workers and employers in all lands.

A vote of thanks to the author of the paper terminated the meeting.

OBITUARY.

Sir Robert Park Lyle, Bt.—Sir Robert Park Lyle died suddenly in London on July 11th. Born in 1859, he was educated at the Madras College, St. Andrews. On leaving school, he joined the family business of Abram Lyle and Sons, sugar refiners, of Greenock. In 1882 he became a partner, being associated especially with the shipowning branch of the firm. He removed in 1897 to London, where he was managing director of the sugar refining business, and was elected chairman in 1908. In 1921 his firm amalgamated with Henry Tate & Sons under the style of Tate & Lyle, which is believed to be the largest sugar refining business in Europe, and Sir Robert became the Chairman. He was created a baronet in 1915, and served on the Royal Commission on the Sugar Supply, from its formation in the previous year. He was elected a Fellow of the Royal Society of Arts in 1914.

DANISH AGRICULTURE AND THE HYGIENE OF THE NATION.

In a Chadwick Lecture recently delivered at the Royal Sanitary Institute, Mr. Nugent Harris gave some interesting particulars of Danish agriculture. Forty per cent. of Denmark's aggregate population, which numbers three million people, subsist on agriculture. This figure does not include the South Jutland

territories, in respect of which there are not yet available agricultural statistics which may be compared with the Danish figures. No other Danish trade provides occupation for such a large part of the Danish population, and thus we may be justified in describing agriculture as Denmark's main industry. We are still further justified in doing so by the fact that among the trades it is first and foremost agriculture which hitherto has supported the economy of the country, procuring through export 80-90 per cent. of the foreign means of payment which is an essential condition of commerce with foreign countries.

In its present form Danish agriculture came into being in the eighties. During these years an important change was effected by which Denmark, from being mainly a corn-selling country, became a corn-buying country, attaching special importance to the production and sale of animal products, more especially butter, pork and eggs and such live stock as slaughter-cattle and draught-horses. These products constituted about 95 per cent. of the total Danish agricultural export.

The means which Danish agriculturists adopted in order to secure this special production was the breeding of a live stock of a very high quality. In the summer of 1914 this live stock consisted of 567,000 horses, 2,463,000 head of cattle (including 1,310,000 head of dairy cattle), 2,497,000 pigs and 15,130,000 fowls. For the support of this stock not only the greater part of Denmark's own crop was required, but also considerable quantities of fodder from abroad, principally about 600,000 tons of oilcakes and about 400,000 tons of maize, the quantity always varying, however, in accordance with the Danish crop. Considerable quantities of artificial manure, nitrate, phosphate, and potash were required to maintain the quality of Danish soil at the level necessary for such an enormous live stock.

Danish agriculture fell into great difficulties during the war, especially during its last phases, when the tightened blockade rendered it difficult to get supplies from abroad. The most strenuous endeavours were used to ward off and mitigate the effects of the blockade, partly by means of forced home production of fodder, partly by means of special efforts to encourage the best breeding material among the live stock. When the seas were re-opened to the free exchange of goods Danish farmers at once proceeded to increase to its full extent the live stock which all quarters admitted to be of vital importance to the future economy of Denmark. These endeavours succeeded.

Before the war 2,463,000 head of cattle existed in Denmark. Of this number 1,310,000 were milch cows. The annual export of cattle and meat was equivalent to about 300,000 head in all, while the export of butter amounted to about 100,000 tons yearly. The exclusion of foreign fodder had a serious influence on the number of the live stock and impaired its capacity, so that the quantity of milk in 1918 was only about half the normal quantity. But now conditions have become again almost normal, and at the same time the Danish butter market has been extended beyond England, and includes Switzerland, Germany, Sweden and Norway, and even America, to which country considerable quantities of Danish butter are sent. In 1922 there were in all 2,286,000 head of cattle, of which 1,113,000 are milch cows, a somewhat lower figure than that of 1914, but, of course, it has not been the poorest animals which have been preserved, but quite the contrary. The quantity of milk is now almost the same as it was before the war.

Industrial conditions applied more to pig breeding than to any other branch of agriculture, and it was, therefore, a natural consequence that it should be hard hit by the blockade. But here again special stress was laid on the necessity of keeping the best breeding animals, and these endeavours were crowned with success, so that the number of pigs is now fully one and a half million as compared with only about 513,000 in 1918. It will not be long before Danish agriculture will reach the level of the stocks held before the war, when the number of pigs was about 2.5 mill. and when the annual slaughtering at 61 Danish abattoirs amounted to about 3 mill. pigs.

As to egg production, this became very important during the war, especially for farming in a small way. Here, again, Danish agriculture hopes soon to be able to produce about 500 million eggs annually, and these, together with 300 million which are eaten in Denmark, constitute the country's total production of eggs. Buyers for this produce are to be found everywhere.

Danish Agriculture and the Rebuilding of Europe.

It is Denmark's belief that increased production is the only way to restore Europe after the war. Danish agriculture is prepared to take part in this task, and it has—as mentioned above in connection with those branches of production which are the cornerstones in agriculture—kept its capacity in effective order, although not unimpaired. Danish soil, which suffered much on account of the difficulty of importing artificial manures in 1918 and 1919, has now regained its former productive capacity. To this circumstance must be added as an invaluable advantage to Danish agriculture the comparatively quiet labour conditions prevailing in this industry. This is a consequence of a feature which is typical of the social structure characterizing Danish agriculture, *i.e.*, the fact that work on the farms is undertaken to a considerable degree by the

farmers' own children, whose term of service is very often only a link in the chain of their education, and one that prepares them for taking over their farms in due course. This is an invaluable advantage which lends Danish agriculture a stability and firmness in production, unmatched in any other industry.

Denmark has become famous for the uniformity and purity in the quality of its main lines of production—butter, bacon, eggs and in recent years cheese. The successful development of its agriculture has also tended to prevent that migration from the rural districts to the towns. The following figures bear striking testimony to this:—

The population of Denmark in 1921 was 3,267,831, of which 1,859,965 lived in the rural districts. This shows an increase of 145,578 over the previous five years, and of 209,615 in the ten years 1911-1921. The men and women about balance in the rural districts.

How the Hygiene of the Nation has been Affected.

Diseases that used to be very prevalent have disappeared, others are much reduced in their virulence. A striking instance is that of the Island of Lolland. At one time it was, owing to its low-lying character, subject to very serious floodings by the sea, leaving the soil very damp and boggy. This affected cultivation and produced also very unhealthy conditions, so much so that Marsh Fever (known over all Denmark as the Lolland fever), bronchitis and similar illnesses, were very prevalent. These conditions continued until 1903, since when reclamation, drainage and afforestation schemes carried out on a big scale have resulted in modification of practically all these illnesses, and Marsh Fever has been eliminated. The soil is now one of the richest in Denmark.

Tuberculosis or—as the Danes call it—Englism Sickness.

In a recent report by the Danish National Society for Fighting Tuberculosis, satisfaction is expressed at the considerable decrease in the number of cases of tuberculosis in Denmark during the last generation, and Professor Faber, in submitting the report, said the tuberculosis mortality figures were now the lowest on record—50% less than those of 30 years ago—and were second only to those of Scotland, and he gave it as his view that in a few years Scotland would be beaten. One of the Directors of the Society—Dr. Ostenfield—in speaking of the report, stated that 80% of the patients in the sanatoria for which they were responsible had been discharged during the year with positive results. The report states that a deficit of 1,293,474 Kroner made on the Sanatoria during the year was met by the State.

FARMING METHODS IN NORTHERN MANCHURIA.

Northern Manchuria is pre-eminently a country of small landowners. The landowner himself works his fields in the majority of cases, but the larger landowners often turn their farms over to tenants.

The division of the land into small parcels and the low purchasing power of the individual farmer have been serious drawbacks to the introduction of modern farming machinery, and Chinese conservatism and loyalty to traditions have also been opposed to new methods of farming. In a district covering an area of approximately 250,000 sq. miles, there are, according to information furnished by one of the large dealers in agricultural machinery, only about 300 ploughs of the American type and some 500 German Sack ploughs. There are only 300 disc harrows, and very few mowers, reapers and self-binders. Even these are not Chinese owned, but belong to Russian farmers who have settled in the zone of the Chinese Eastern Railway.

In northern Manchuria, according to a report prepared in the American Consulate at Harbin, the land is very carefully worked, great attention being paid to fertilisation. The land is ploughed in parallel ridges and furrows. The soil is worked twice, which enables the roots to draw moisture from the night air, even in time of drought.

The plough used is very primitive. Into a wooden frame is set a spade-shaped ploughshare, which is clamped to the bent wooden lever or beam. The other end of this lever serves as a handle, and at the middle of it is fastened a grader. The ploughshare is held in almost a perpendicular position to the surface of the land and tears it effectively. This plough is usually drawn by two animals (horses, mules or oxen) and is attended by two labourers, one of whom guides the plough and the other the animals. It is transported to and from the field on a special wooden drag.

There are two methods of ploughing the soil. Either the ploughshare follows the ridge, and where last year there was a ridge there will be a furrow this year, or the ploughshare follows the furrow, and where last year there was a furrow there will also be a furrow this year.

Sowing or seeding is seldom performed by hand, the use of a "chan hu lu" being more popular. This is a dried pumpkin, which has an opening made in the narrow end. The pumpkin is filled with seeds and the opening is then closed with a cork, into which is fitted either a reed or some kind of piping in such manner that the seeds will scatter if the instrument is slightly tipped and lightly tapped with the hand. One workman, carrying the "chan hu lu," walks along the furrow, and tapping the pumpkin with his right hand, he

scatters the seed so that they fall on the ridges. Another man, walking along the ridge, stamps the seeds down with his feet. Behind them follows a third man, with a horse which pulls a small stone roller. This roller follows the two ridges. On the new ridge it levels out the crest, and on the other it smoothes out the tracks of the second labourer's feet and covers the seeds with earth.

When weeds begin to appear the Chinese farmer once more follows along the furrows with his plough, deepening them by half a foot so as to surround the sprouts with fresh earth. When the sprouts have reached considerable height the plough is again used for bringing the deeper roots closer to the surface, thus enabling them to absorb more moisture from the air. By this process weeds are also destroyed between the ridges. On the ridges themselves weeding is done by means of hoes.

For the harvest of cereals the Chinese farmer uses a special scythe, which is similar to the American scythe but of smaller dimensions. Very few Chinese farmers in Northern Manchuria are familiar with flails. In threshing, the plants are placed in a circle, with heads toward the centre, and over these is drawn by animals a heavy stone roller. Before the kaoliang is threshed, however, the heads are cut off from the stalks to prevent these being spoiled by the roller, for the kaoliang stalk plays an important role on the farm, inasmuch as it is used for roofing, fencing, fuel, and many other purposes. The roller process is continued until all the grains have been removed. Winnowing is done with shovels and old-fashioned hand sifters.

The threshed and cleaned grain is stored either in pits or in specially constructed cylindrical silos, covered with a conical roof. These silos vary in size according to the requirements of the individual farm. They are built of poles, which are plaited with dry twigs, the whole structure being plastered inside and outside with a composition of clay and straw cuttings. It is divided into two or three compartments for the different kinds of cereal. Besides these silos the Chinese employ so-called "chantze." These resemble wells and are made of boards.

The threshed grain is ready for the market and for the feeding of cattle. For preparing human food, however, it is necessary that the hulls be removed. This is done by the "chantze"—a round, stationary, horizontal millstone, upon which rotates a stone cylinder with a rough surface. This cylinder is usually moved by small donkeys.

The Chinese plough is particularly unsuitable for breaking new ground, and this is one reason why the Chinese farmer is reluctant to take up virgin land. Some years ago the Government conceived the idea of ploughing up large tracts of land in order to sell them to immigrants from the south. It is believed the plan fell through because of some unfortunate financial manipulation in connection with the purchase of machinery. It seems, nevertheless, that this idea may be revived by some enterprising manufacturer, with a view of introducing modern farming machinery on a large scale through the agents of the Government. There appears to be a tendency at the present time to encourage immigration into the Nonni Valley and other parts of Heilungchiang Province.

The Chinese Eastern Railway, which maintains two agricultural experiment stations in the district—one of 300 acres at Station Anda, and one of 250 acres at Old Harbin, together with an experimental farm of 700 acres at Station Echo, appropriated 60,000 gold roubles for farming experiments during the year. The representative of a large American firm has been conducting tractor trials on these grounds, and they are generally reported to be exceptionally satisfactory. Two tractors are being experimented with—one pulling two-bottom ploughs and the other pulling four bottom ploughs. This representative is of the opinion that the future of these tractors in Northern Manchuria is most encouraging.

The market in northern Manchuria appears to be worthy of study on the part of manufacturers of agricultural implements, especially the smaller type of implements, such as ploughs, cultivators, seeders, threshers, and fanning mills.

GENERAL NOTE.

Bracken as Pig Food.—Some time ago, Mr. Loudon M. Douglas, of Newpark, West Calder, Midlothian, directed attention to the use, which in past times had been made in some parts of Scotland of the bracken roots, which, it was pointed out, consist of Rhizomes, and are very nourishing to pigs. Since then a great many landowners and farmers who have bracken infested land have been trying the folding of pigs on these areas, and it would be an immense advantage if those who have been doing this would state their experience so that it may be of service to others. The subject has proved to be of interest in other countries also, and it would appear from a report obtained by Mr. L. A. Evans, Secretary of Agriculture, Tasmania, that it is quite a common thing to fold pigs on bracken there. One correspondent, who has been a breeder of pigs in Tasmania for over 50 years, states that pigs in various parts of Tasmania are put on to fenced areas carrying bracken fern which they root up for the Rhizomes and which they much relish. The pigs should be given plenty of water and enough food to keep them going, but in one instance—at Cambridge in Southern Tasmania—they did so well on the Rhizomes that the extra food was cut out. Breeding sows, between the litters, cannot, in his opinion, be doing anything better than rooting ferns. Light sandy country or soil easily moved is the most suitable for this work.

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICES.

DOMINIONS AND COLONIES SECTION.

A meeting of the Dominions and Colonies Section was held on Tuesday, July 17th. Present—Lord Blyth (Chairman of the Committee) in the Chair, Mr. A. H. Ashbolt (Agent-General for Tasmania), Mr. Byron Brenan, C.M.G., Mr. Edward Dent, M.A., Sir Thomas H. Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S., and Sir Charles W. Metcalfe, Bt., with Mr. S. Digby, C.I.E. (Secretary of the Indian and Dominions and Colonies Sections.)

REPORT ON THE "OWEN JONES," "MULREADY" and "NORTH LONDON EXHIBITION TRUST" PRIZES COMPETITION.

With the kind assistance of the Director of the Victoria and Albert Museum, the Council again arranged for a competition of students of Schools of Art in accordance with the terms of the Owen Jones Trust. Notices were issued in October last stating that six prizes would be offered under the usual conditions, each prize consisting of the Society's Bronze Medal, and a copy of a book or books on Applied Art, of a value not exceeding £2, to be selected by the successful competitors. In addition to these a Special "Mulready" Prize of £20 was offered for the best design (irrespective of class) submitted. The subjects of the competition this year were:—

Domestic Pottery and Table Glass.

Metalwork: including work in Precious Metals, Ironwork, Jewellery, Enamelling, etc.

Textiles: Including Lace, Embroideries, Openwork, Dress Brocades, Dress Designs, and Costume Accessories (including Fans), Printed Fabrics for Dress.

The date for the receipt of competing designs was fixed for June 15th, 1923, and arrangements were made for their inspection at the Victoria and Albert Museum.

The following judges were appointed by the Council to consider the designs submitted:—Sir Frank Warner, K.B.E., Dr. G. F. Assinder, Mr. A. F. Kendrick (Department of Textiles, Victoria and Albert Museum), Mr. H. P. Mitchell (Department of Metalwork, Victoria and Albert Museum), and Mr. Bernard Rackham (Department of Ceramics, Victoria and Albert Museum). Mr. W. W. Watts, F.S.A. (Department of Metalwork, Victoria and Albert Museum), was also appointed, but was unable to attend.

The centres represented were (the figures in brackets show the number of entries in each case):— Bath (2), Belfast (1), Birmingham (1), Bilston (2), Blackburn (16), Chester (2), Croydon (5), Darlington (9), Derby (8), Farnham (1), Glossop (2), Gloucester (3), Horsham (1), Hyde (8), Ipswich (3), Keighley (1), Kingston-on-Thames (2), Lancaster (1), Leeds (14), Leyton (7), Liverpool (1), London: Camberwell (1), Hammersmith (4), Hornsey (1), Westminster (St. Martin's) (2), Macclesfield (13), Manchester (7), Morecambe (3), Newport (1), Nottingham (8), Stoke-on-Trent (1), Sheffield (1), Southend (12), Tunbridge Wells (3), Wallasey (3), Watford (12), West Bromwich (12).

One-hundred-and-ninety designs were submitted by 174 candidates from 38 centres. They were divided as follows:—Embroideries (91), Dress Fabrics (41), Lace (14), Fans (8), Costumes (5), Metal work and Jewellery (27), Pottery (4).

The Judges have much pleasure in reporting that the general standard of the work is distinctly higher this year than usual, and there are more works of outstanding merit. Whereas in 1922 they recommended the award of only five of the six prizes annually offered, they feel obliged this year to recommend that seven prizes should be awarded, as follows:—

One half the Special Prize of £20, the Society's Medal and a Prize of Books to the value of £2, to:—

Emma Seel, School of Art, Macclesfield (Openwork Corner of Embroidered Table Cover).

S. Griffin, School of Art, Nottingham

(Design for an embroidered machine-made lace bedspread with worked portion).

The Society's Medal and a Prize of Books to the value of £2, to:—

Norman Dawson, School of Art, Macclesfield (Printed Silk Dress Fabric).

George Kershaw, School of Art, Macclesfield (Woven Silk Dress Brocade).

Ethel Mary Bennett, School of Art, Newport, Monmouthshire (Design for a Silk Brocade with sketch of suggested use).

Kathleen Goodwin, School of Art, Stoke-on-Trent (Pottery Statuette "Will o' the Wisp.")

George Sidwell, School of Art, Technical Institute, Leyton, Essex (Silver Rose Bowl and Copper Cream Jug).

The following were Highly Commended:—

Winifred Mary Joyce, School of Art, George Street, Croydon, Surrey (Embroidered Tea Cosy).

G. Thornton, School of Art, Leeds (Design for a Dress Fabric).

Harry Worsley, School of Art, Macclesfield (Woven Silk Dress Brocade).

Kathleen V. Tarr, School of Art, Macclesfield (Painted Silk Fan).

Gwendoline E. Mountain, School of Science and Art, Watford (Enamel Plaque on Copper).

The following were Commended:—

Margaret Smerdon, School of Art, George Street, Croydon (Worked Panel in Embroidery).

Mary Ridehaugh, School of Art, Technical College, Darlington (Design and Worked Specimen for an Embroidered Table Runner). [The commendation is given for the Design only, and not for the execution.]

Dora Power, School of Arts and Crafts, Derby (Design and Work for Embroidered Table Cloth).

Andrew Millin, School of Art, Technical School, Hyde (Design for Printed Dress Fabric).

Edna Horrox, School of Art, Leeds (Embroidered Night Dress Case).

Kate M. Mills, School of Art, Technical Institute, Leyton, Essex (Embroidered and Cut Linen Table Cloth).

Isabel Ferguson, Municipal School of Art, Cavendish Street, Manchester (Embroidered Cushion in Black and Gold).

Hilda F. Collins, Municipal School of Art, Cavendish Street, Manchester (Appliqué Panel for Back of Bed).

Elsie Wood, Municipal School of Art, Cavendish Street, Manchester (Night Dress Case embroidered with Wild Flowers in Silk).

P. Meadwell, School of Art, Nottingham (Design for machine-made Lace Bedspread).

G. L. Darker, School of Art, Nottingham (Design for machine-made Filet Lace Cushion Square).

Gladys Jones, Ryland Memorial School of Art, West Bromwich (Embroidered Panel and Sketch).

Kathleen A. Gray, Ryland Memorial School of Art, West Bromwich (Linen Nightdress Case in Cut Work).

N. Leach, School of Art, Ipswich (Design for Panel of Filet Lace).

J. Kirkbride, School of Art, Lancaster (Limerick Lace Collar).

Amelia Clarke, Municipal School of Arts and Crafts, Southend-on-Sea (Point Lace Tea Cosy).

P. Chinnery Brown, School of Arts and Crafts, Hammersmith, London (Designs for Fans).

Phyllis Bamford, School of Art, Macclesfield, (Painted Silk Fan).

Richard Ruby, School of Art, Bilston, Staffordshire (Brass Salver).

Muriel A. Noble, School of Art, Leeds (Cloisonné Enamel).

Thomas W. Swindlehurst, School of Art, Leeds (Gold Brooch).

Edith M. Shepherd, Municipal School of Art, Cavendish Street, Manchester (Hair Ornament in Plique à jour Enamel).

Arrangements have been made for the exhibition to the public of the competing designs as in previous years. They will be on view from August 4th until September 16th, from 10 a.m. to 5 p.m. in the Class Room, Department of Textiles (First Floor), Victoria and Albert Museum, South Kensington, S.W.

In announcing the awards, the Council desire to express their thanks to the Judges for the trouble they have devoted to the work, and for the promptitude with which the awards have been made.

They wish also to state their appreciation of the assistance rendered to the Society by the Director of the Victoria and Albert Museum and his staff.

The full conditions and arrangements for the Competition in 1924 will be announced later.

PROCEEDINGS OF THE SOCIETY.

DOMINION AND COLONIES SECTION.

TUESDAY, JUNE 5TH, 1923.

HIS GRACE THE DUKE OF DEVONSHIRE, K.G., P.C., G.C.M.G., G.C.V.O., Secretary of State for the Colonies, in the Chair.

THE CHAIRMAN, in opening the meeting, said that all present were looking forward with the very greatest interest to the address about to be given by Sir Edward Davson. The subject was very large and very interesting and one in which he hoped people in this country were taking an ever-increasing interest. In bygone days there might have been a certain amount of suspicion that people were not taking that interest in great Imperial matters that they should do, but he hoped that was not the case to-day. It was well-known what had been accomplished in the stress and strain of war and he believed the surest and soundest method not only of solving the difficulties of the immediate moment, but of making the Empire stronger and greater, was by all working together to this end.

The paper read was:

THE ECONOMIC CONFERENCE AND THE COLONIES.

By SIR EDWARD DAVSON.

It will be remembered that one of the first steps of Mr. Bonar Law's Government on taking office was to announce their intention of calling together an Economic Conference where the appropriate representatives of the Dominions would take counsel with the Government here as to the best means of developing Empire trade. This conference will commence its sittings on October 1st, and as my text to-day I shall take the programme as so far indicated :

(1) Ways and means for further development of the natural resources of the Dominions and the Colonies.

(2) Inter-Imperial commerce, shipping and communications generally.

(3) Co-ordinated action for the improvement of technical research.

(4) The unification of law or practice in the Empire in certain matters affecting trade development.

It is further stated that the conference will include representation of the Colonies and Protectorates, and this is satisfactory as indicating that the interests of the Colonies, as distinct from the Dominions, are not to be forgotten. It is obvious in this connexion that while there may be many questions which apply to the Dominions alone, the combined interests of the two are frequently concerned, and the views of the Colonies are, therefore, necessary if the best solution of the problems involved is to be found.

How much of the time of the Conference can be devoted to purely Colonial matters remains to be seen, for it must naturally be assumed that the affairs of the Dominions will claim the major part. That the Colonial problems are of interest and importance I shall endeavour to show, and it is my hope that it may be possible to evolve from them some definite and continuous policy of development ; for although circumstances and conditions may vary in different Colonies I think that there may be found an underlying principle of development, a Colonial system let us call it, which may be common to all. It may be that the seeking for this principle should rather be left to a Colonial section of the Conference presided over by the Secretary of State. It may be alternatively that more rapid progress would have been made if the Governors and commercial representatives had been called to a Colonial Conference as an auxiliary to the greater one, but we must consider things as they are and assume that Colony problems will receive adequate consideration at the Conference as it is now being organised.

The matter of their representation is, however, not without difficulties. They obviously cannot expect the same status as the Dominions and, even so, the presence of representatives of each of them would unduly increase the size of the assembly. On the other hand, to create outside advisory committees to deal with points affecting the various Colonies would scarcely meet the case, as it would be impossible for those not present at the Conference to adapt their views to the varying phases of the discussions. I suggest that for the purposes of the Conference, the Colonies might be divided into four main groups, namely, East Africa, West Africa, the Far East and the Atlantic—although exceptional cases might call for additional members—and that an individual representative of each should attend the Conference in an advisory capacity with limited rights as regards addressing it. In this way the whole of the Empire would be represented and the interests of these Colonies would be more certain of recognition.

I propose this afternoon to indicate some of the problems involved, but in the first

place it may be desirable for me to refer individually to our world-encircling girdle of Colonies and Protectorates.

By way of the Mediterranean and passing Malta and the historic island of Cyprus, with its wheat, barley, fruits and mineral production, we come to the Anglo-Egyptian Sudan with its great cotton growing potentialities, due largely to the development of irrigation. Its area is over a million square miles and its population is nearly six million souls, but the status of the Sudan as a part of the Empire is not that of a Colony and I, therefore, do not dwell on it to-day.

Let us then pass by Aden with its 9,000 square miles of protectorate, past the Somaliland Protectorate with an area of 68,000 square miles, a population of 300,000 and an export of skins and hides, gums and resins, until we pause to consider our great possessions in East Africa.

These include Kenya Colony, Uganda and Zanzibar Protectorates with the mandated territory of Tanganyika, having an area of 676,000 square miles and a population of nearly ten million. Naturally this vast territory—over five times as large as the United Kingdom—has great variations of soil and produces many and varied commodities. The low lying areas of Kenya constitute a large field for development, but there is a paucity of population. In the higher districts the population is more ample. Coffee, sisal, maize and flax are the staples and the potentialities of the country are great for cattle raising and dairy produce. In Uganda cotton is the principal product, while coffee, oilseeds and hides are also exported. Zanzibar, which it is interesting to recall came under our control in 1890 in return for ceding Heligoland to Germany, yields the bulk of the world's clove supplies, while Tanganyika—formerly German East Africa—has nearly three million acres of forest lands with potentialities for the manufacture of paper pulp, produces similar crops to the others—and on its lower river banks has great possibilities in the way of sugar production. One must emphasise, too, the great value of its salt deposits. The administration of these several East African countries is at present entirely separate and it may be hoped that some day the appointment of a High Commissioner may be possible who can combine the various interests and co-ordinate the different systems of Government and taxation.

If we move to the other side of the Continent we have our possessions on the West Coast, namely, Nigeria, the Gold Coast with Ashanti, Gambia and Sierra Leone, of which Nigeria has, apart from India, by far the largest population of any part of our overseas Empire. Its main products are palm oil and kernels, rubber, and other tropical products. It has already 1,000 open miles of railway, and several thousand miles of telegraph wires. Its harbour at Lagos is developing and altogether it is a land of promise and one of the most valuable possessions of the Crown. To it, I should add, is attached the mandated territory of Cameroon with 400,000 inhabitants and 31,000 square miles of fertile land.

The Gold Coast with an area of 80,000 square miles has, compared with Nigeria, a more limited supply of labour, is making steady progress, and I doubt if any other Colonial Government is in a happier financial position. It produces palm oil and gold, but its main industry is cocoa grown by native small holders under their various chiefs. It is interesting to note the progress of the West African cocoa industry, which from small beginnings—and stimulated by the preference given—has now reached 80 per cent. of the total imports into this country, while it is confidently expected that the output will yet largely increase. Further railway construction is in contemplation to feed the harbour which is now being constructed at Takoradi, and it may be hoped that systematic development, without exceeding the bounds of financial prudence, may prove beneficial to the Colony. To the Gold Coast is attached the mandated territory of Togoland.

The Colony of Sierra Leone, it is interesting to note, originated in the sale in 1788 by a native king to English settlers of a piece of land intended as a home for natives of Africa who were waifs in London, and later it was used as a settlement for Africans who were rescued from slave ships. Its area with its Protectorate is 31,000 square miles with a population of 1½ millions. Its capital, Freetown, is the greatest seaport in West Africa and its main exports are kola nuts and palm kernels.

The Gambia Colony and Protectorate, which was discovered by the early Portuguese navigators, has an area of 4,134 square miles and a population of 209,000, its chief export being ground nuts.

If we journey southward we come to Rhodesia, the territory of which is under the administration of the British South Africa Company. The region north of the Zambesi is known as Northern Rhodesia and that south of the Zambesi—Matabeleland and Mashonaland — as Southern Rhodesia, this latter district being about to become a self-governing colony. The total area is 440,000 square miles, with a population of 1,736,000. Both agriculture and mining are well developed and it produces maize, tobacco, gold, cattle, coal and minerals and also has a vast amount of arable land.

The Nyasaland Protectorate lies between Rhodesia and Tanganyika and has an area of 39,573 square miles, with a population of twelve hundred thousand. Of products one may mention the growth of tobacco and cotton. So much for Africa.

Now let us move east from Kenya across the Indian Ocean till we reach the 90 islands of the Seychelles, first colonised by the French in the middle of the eighteenth century, the object being to establish plantations of spices to compete with the Dutch monopoly and which in 1921 produced 26 million coconuts. Nearly a thousand miles due south lies the bilingual island of Mauritius, bilingual because the French held it for the greater part of the eighteenth century. It relies mainly on its sugar crop, now stimulated by the British preference, the value of which this year will be near £6,000,000.

So we pass farther across the ocean to another wealthy island, that of Ceylon, with an area of 25,000 square miles and a four and a half million population. First heard of in the fifth century B.C. and made a Crown Colony in 1802 it is well developed and has 820,000 acres under coconuts, 800,000 under rice, while tea and rubber have each 400,000. The importations into this country of Ceylon tea, on which a preference is granted, amounted in 1921 to £6,650,000.

Yet further east we have the Straits Settlements comprising Singapore—with its great transit trade—Penang and Malacca—the oldest European settlement in the East—and also the Cocos Islands; the Governor of these is the High Commissioner of the Federated Malay States, while contiguous to these are the Unfederated Malay States. These are famous for their rubber estates, for their copra, rice and tin production. Their total area is 46,592 square miles and their population 3,177,000.

And again further east, we reach British North Borneo—administered by the British North Borneo Company—together with Brunei and Sarawak under British protection. The chief exports are timber, tobacco and rubber, while the area is 77,000 square miles and the population 1,000,000.

We now pass on by way of the busy port of Hong Kong into the Pacific, and, without referring to the many alluring islands scattered over this Ocean, some of them mandated to Australia and New Zealand, we come to the Fiji Islands consisting in themselves of 250. Fiji is exactly on the other side of the world from us and is known best for its sugar production, helped in the past by the systematic immigration of labourers from India.

So we pass across to the Atlantic, where our northernmost possession is the little island of Bermuda with its flower and vegetable production and an added prosperity from its tourist traffic from America. Farther South we have the Bahamas with their sponge and sisal industry and then Jamaica with its historic associations and holding a key position over the Panama Canal, the main products of which are sugar and bananas. To the west run down the Leeward and Windward West Indian Islands, the cradle of the British navy, with their production of sugar, cocoa, cotton, limes and fruit and we also have the sugar isle of Barbados with its ancient constitution and proud of the fact that it has never been aught but British since 1625; and Trinidad—a progressive island—with a production of sugar, cocoa and oil. The combined area is 12,206 square miles and population 1,725,000. In Central America is the little known and still less developed Colony of British Honduras with 8,500 square miles, 45,000 people and an export of mahogany, chicle and other products; and on the mainland of South America we have British Guiana, with an area of 89,000 square miles, captured in 1796 and since then best known for its sugar production. The potential wealth of its interior is scarcely yet touched, and still awaits development, although diamonds, gold, timber and balata all contribute to its revenue. The absence of adequate population is its prime handicap to development and it is hoped that opportunity may be taken at the Conference to reopen negotiations between British Guiana and India for the resumption of emigration

from that country.

And so to that remote Colony in the South Atlantic, the Falkland Islands with South Georgia and other dependencies, with an area of 7,300 square miles and an export of whale produce and wool.

Such is a flying survey—imperfect though it be—of the extent and resources of our Colonial Empire ranging from the torrid zone of the equator to the borders of the Antarctic circle. The names of places and products conjure thoughts of romance and history, of tropical luxuriance and riches, of strange tongues and races. But our concern is now only with the commercial aspect—not even with the extraordinary variety of administrative problems—and our aim is how to find the best methods for fostering the natural prosperity of these colonies. Let me then sum them up in a word—omitting the Sudan they have an area of two million square miles, a population of 49 millions, an annual trade of over £550,000,000 and a public debt of only £61,000,000. Their trade with the United Kingdom—import and export—may be roughly taken as £100,000,000 a year, which you will agree is, therefore, already valuable but which we hope to make much more valuable.

In respect of these colonies our object must be twofold; firstly, to increase their productive power and develop their mineral resources so that their internal wealth may grow, and, secondly, to see that the growth of demand for manufactured goods consequent on the increasing wealth may be filled by this country—and by those parts of the Empire which can meet the demand—rather than by foreign countries.

How are we to achieve this development of colonial resources? Undoubtedly by the improvement and extension of transport facilities, so that the cost of existing products may be reduced, while new areas of undeveloped land are brought into beneficial cultivation.

And to pursue the question another stage—what is the best way to further this? I would submit that preference should always be given to private enterprise and that every inducement compatible with the Colony's welfare should be offered to the intending investor. There are, however, propositions which cannot tempt the private capitalist owing to the reward being too remote, and the next alternative is for the Colony itself to be permitted to raise loans in the London market in order that it may be placed in a position to undertake the work. But even this will sometimes fail as a solution, for it can be understood that there may be works which will require many years in order to become remunerative, and if the Colony cannot meantime afford to provide the necessary interest and sinking fund it will decline to face the undertaking, and so development will be checked.

On such occasions the Imperial Government might well consider the advisability of advancing the amount required and either funding or waiving the interest for a period of years as may be considered best, thus ensuring that the Colony is given breathing time to earn the profits before having to pay the charges. Otherwise one reaches the paradoxical argument that a Colony cannot become wealthy until it is developed and that it cannot become developed until it is wealthy enough to pay for it. One would, however, like to go a step farther than this and urge that a definite scheme of development be planned out for a period ahead so that each Colony may know the lines on which its development will proceed and each Governor will carry on the programme of his predecessor—I speak in general terms—thus ensuring the uninterrupted progress of the Colony.

So much for development, but as this comes about—as the jungle and the bush give place to economic crops—what is to be the market for these? One cannot obviously guarantee that a profitable market will always be found. But one can surely offer some security of market, and, assuming that this country requires certain commodities, it is not too much to ask that, wherever duties may be imposed to meet our needs of revenue, a preference should be given to our Colonies as against the foreigner, so that whatever be the world's price—whether profitable or not—they may know that we look to them in the first place to supply our wants. That this is no act of altruism I shall hope to show, but before doing so I shall venture to give an example.

Let us take the case of sugar: Before the War we drew 80 per cent. of our sugar supplies from Europe and 3 per cent. from Empire sources. When the war came, we were faced with a sugar famine, but fortunately for us the United States, which, like us, had once been dependent on foreign supplies, with a prescience that

compels admiration, had steadily, by a system of preferential tariffs, built up a supply for their domestic needs in Cuba and other territories under their control. In the war crisis we turned to these supplies, and we have continued to avail ourselves of them until now in 1923 we are drawing 50 per cent. of our sugar needs from American sources and will this year remit £40,000,000 to America in payment for them. It is true that an attempt has been made to remedy this unsatisfactory state of affairs, and, by the granting of a preference of one sixth of our duties, we have this year imported 15 per cent. of Empire sugar. But this rate of progress is too slow, or in other words the rate of preference is too low. We know that in the Empire we can grow enough sugar to supply all our needs, and if the preference were increased from one sixth to one third and stabilised at the present amount—as recommended by Hon. Edward Wood when Under Secretary of State for the Colonies in his report on the West Indies —the growing of sugar would receive a great stimulus thrughout the Empire.

I have said that such help by the Mother Country is not altruistic since it is to be presumed that the proceeds of sale in a great measure will be remitted to the Colonies in the form of manufactured goods. Every bargain must have two sides and on the side of the Mother Country I think it should be stipulated that whenever loans are raised here, all orders for supplies in connexion with the enterprise in view should be placed in this country; and in respect of preferences, these call for reciprocity, and just as a Colony may ask for a preference on its products here, so should the Mother Country expect a preference on its exports to that Colony. I venture to suggest that our aim should be to establish an all round Imperial Preference and that the rate should be 33⅓ per cent. It is hoped by some that we shall some day see free trade within the Empire, but I fear that this hope is remote, for our dominions have a natural desire to protect their own manufactures and our Colonies are largely dependent on their customs duties for their revenue. I know that there are difficulties in establishing even the one third remission, and this applies especially to the Dominions. Canada—the pioneer in Empire preference—grants 33⅓ per cent. but Australia for the most part only gives 10 per cent., New Zealand from 10 to 20 and South Africa 3 per cent., and the matter is not simplified by the introduction of intermediate tariffs. As regards the Colonies, British Guiana and some of the West Indies grant 50 per cent., others 33⅓ and 25, while Fiji gives from 45 to 50 and Cyprus 16⅔. No other colony to my knowledge grants a preference to this country and East Africa is, I think, hampered in this respect by a foreign treaty which, however, can be denounced by giving six months' notice. I shall not dwell on this subject, but earnestly urge the recognition of the principle of reciprocity and of the establishment of an Empire tariff for an assured period of years, and I would only add that the granting of a preference, if worked out by a scientific readjustment of tariff, does not necessarily mean a loss of revenue to those concerned.

As to shipping, the ocean transport of produce and goods, I feel that little need be said, for I think that shipowners feel that the less they are interfered with the more likely they will be to maintain that commercial supremacy on the seas which has so long been ours. I might, however, emphasise the benefit to producers of the lowest possible rate of freight and venture the hope that British goods between British countries may be transported in British bottoms; in this connexion I would draw attention to the recent striking increase of the German mercantile marine and to the fact that last year the tonnage increased 1,170,000 tons, whilst the combined merchant fleets of the British Empire, United States, France, Japan, Italy, Greece and Belgium increased only 735,000 tons.

With regard to the carriage of goods, you may be aware that the Maritime Law Committee of the International Law Association, when in Conference at the Hague in 1921, drew up what are called the Hague Rules, defining the relative obligations of shipowners and shippers under bills of lading. A bill embodying the essential features of these rules is now before the House of Lords and, should it be passed, the opportunity will doubtless be taken at the Conference next October to urge on all parties the desirability of passing identical acts so as to ensure uniformity throughout the Empire in this important matter. The same remarks also apply to the findings of the Imperial Customs Conference of 1921 wherever these have not so far been given effect to in local legislatures.

The development of wireless telegraphy and telephony must have a most important

bearing not only in the field of administration but also in that of commerce in our Colonies, for it is obvious that business is much simplified if traders can converse by telephone over distances of several hundred miles, where otherwise communications might take several weeks. Indeed its effect in the development of remote and outlying parts of Colonies can scarcely yet be realised, for it brings the far off settlements, the lonely pioneers, miners and backwoodsmen in daily touch with civilisation, facilitating their work, adding to their personal security and increasing the amenities of life. Nor must I forget to refer to aviation, which, not only by the transport of passengers and mails to remote hinterlands where means of communication are slow and rare, but also by carrying out aerial surveys where ground ones are too difficult or costly, is bound to play an important part in future Colonial progress.

I might also here touch on the question of unification of law in respect of merchandise marks, trade marks and patents, although this is a complex subject which deserves a paper of its own. Briefly, however, the aim is twofold, to prevent unfair competition and the Imperial recognition of rights of industrial and intellectual property. The present Merchandise Marks Law has been adopted in principle by the majority of colonies and this provides some remedy for the evils which are so rife in trade, namely, imitation of get up, the use of other firm's names, &c. The whole question was recently considered by a Departmental Committee and the recommendations have been largely embodied in a bill which has recently been before Parliament. If this is passed, it is to be hoped that the Colonies will be urged to adopt the recommendations made therein.

As regards unfair competition by the illegal use of trade marks and false indication of origin, this is dealt with internationally by an International Convention and an International Agreement, the latter usually called the Agreement of Madrid, but of our Colonies only Ceylon and Trinidad have so far become adherents to this, and it may be considered whether a larger number of Colonies cannot accede to these conventions by passing, if required, the necessary legislation. There is the further question of the universal registration of trade marks throughout the Empire, possibly by some such means as the group system adopted by the "General Convention of American States as regards the Protection of Trade Marks" in 1910. Thirdly in regard to patents, the British Empire Patent Conference sat during June of last year and produced two schemes, the provisional scheme recommended for immediate adoption consisting in Colonies accepting for registration within a specified period any patent which has been actually issued in this country—the registered patent enjoying all the privileges of a patent actually issued in the Colony. A further recommendation is that the fees throughout the Colonies should be substantially lowered. The report of this Conference is published and one may hope it too will receive consideration at the Conference.

I have already spoken of the granting of a preference as an encouragement to production, but it should be borne in mind that this is not a complete solution in itself. It is only a contributory one and its success in this respect is dependent on an ever increasing efficiency in production. Apart from key industries, the aim of a preference is not to preserve by subsidy an industry which, in the phrase of political economy, is outside the margin of cultivation, because, if a production is on an economically unsound basis, it must eventually come to grief. The aim rather is to assist it in its earlier stages, to shield it in its delicate youth from the fierce onslaught of foreign competition and to give it opportunity, if it be of riper age, to absorb that scientific knowledge which is the life-blood of modern agricultural and industrial life and without which any industry must assuredly be beaten in the struggle for existence. Let me instance the case of cotton. About 70% of our cotton comes from the United States and large sums are annually remitted there in payment. But, further, the American crop, owing to the boll weevil will diminish rather than increase in the future, while their own manufacturing industry is steadily growing and the need of providing adequate supplies to this country is therefore a matter of serious concern. Already efficient steps are being taken to provide our needs from within the Empire and the system initiated by the Empire Cotton Growing Corporation bears on my point. The levy of 6*d*. per bale instituted on all cotton consumed in the United Kingdom—wherever grown—is used, not to increase the price, but to form a fund which is able, by the provision of

expert advisers, of research, of experimental stations and seed nurseries, to establish the industry on what we may hope will be sound and lasting foundations. So I confess that—although the idea be fanciful—I would like that any extra amount received in price from a preference be regarded not as an addition to the income or dividends of the recipient, but as constituting a bonus to be used for the improvement of methods of production, which is the only ultimate guarantee of the permanent preservation of an industry.

Already as regards scientific institutions I think we can look on our progress as satisfactory; for we have now various bodies established for this purpose including the Bureaux of Mycology and Entomology to combat diseases and pests. In the Colonies themselves we have the newly-founded Agricultural College in Trinidad and there is a welcome growth of interest in the Departments of Science and Agriculture and Mines; while the growing co-operation of those on the spot and those at home in the circulation of information must all tend to raise the whole subject of agriculture to a higher plane. Nor must one forget to refer to the need of encouraging both mineral and economic surveys—the machinery for which already exists at the Colonial Office—and the important influence exercised by the researches and discoveries of the London School of Tropical Medicine. The health of the people, apart from everything else, means much to agriculture, for it is obvious that whether it be small farmers or paid labourers who are affected by malaria or other of the many ills which flesh is heir to in the tropics, sickness does much to weaken the individual, to lower the standard of efficiency and consequently to reduce the amount of output. I must mention too the Imperial Institute in London, the main object of which is to investigate Empire products scientifically with a view to finding markets for them and to indicate how best they can be prepared for such markets, and furthermore to initiate enquiries in the various Colonies for these articles, the economic use of which has not so far been realised. An enquiry is at present being conducted into the working of the Institute, especially with reference to its relations with other scientific bodies, and its report will doubtless come before the Conference. In fact, the whole system and scale of Colonial contributions to these various organisations calls for attention and review.

I think that I have now said sufficient to indicate the nature of the Colonial problems which call for consideration, and in doing so I do not mean to imply that they have not already been receiving attention, more especially in the Colonial Office. One sometimes hears or reads criticisms on this department in its relations with the colonies but, whatever may have been in days gone by, I feel that such attacks are unjustified in recent times. Looking back only for three generations of Secretaries of State—for I need not go back to the time of Mr. Joseph Chamberlain, whose vision was so inspired and whose dreams are daily turning more and more into realities—I would recall the combination of Lord Milner and Mr. Amery as Secretary and Under Secretary of State, of Mr. Churchill and Mr. Edward Wood, and now of the Duke of Devonshire, our Chairman to-day, and Mr. Ormsby Gore as being combinations who have worked and are working strenuously for the furtherance of Empire development. My aim to-day, while recognising the good work of the past, is to suggest that the time has come for the evolution of an Imperial system and for further scientifically-planned development, coupled where possible with economies in administration, in order to secure the welfare and prosperity of these possessions overseas.

And in conclusion I would add but this; we have been discussing only questions of material progress and economic development, but behind these there lies something deeper and greater. There has, by the dispensation of Providence, been given to our charge the care of these fifty million people of many races around the world. Their material welfare is important, but beyond this there falls upon us the care and responsibility for their moral and mental progress, of educating them and uplifting them to an ever higher plane of civilisation. It may be said that this thought is not relevant to a paper on commercial matters, and with this I must agree. It may be said that it is not relevant to an Economic Conference, but of this I am more doubtful. For, in the discussions that are to be held, I think that there will be ever present in the minds of all the thought that matters of production and trading are only a means to an end, that, important though they be, they are but a part of that task—which is our British heritage—of guiding and guarding the welfare of the many millions whose destinies are committed to our charge.

DISCUSSION.

THE CHAIRMAN expressed, on behalf of the audience, their sincere appreciation of Sir Edward Davson's extraordinarily interesting and valuable paper. He was glad that the Author laid stress on the duty which devolved upon those in office and those taking a lead in the work of areas in every part of the world in the upbringing of the inhabitants as well as in the economic and material development of those areas. The more that duty was realised, not merely by those who might be from time to time placed in a position of responsibility, but by the community as a whole, the better would be the appreciation of the problems which lay before the country. There was a ring of confidence in the address, and he thought he saw running throughout it an indication that great as had been the progress of the Empire in recent years, there was still, if we were true to our trust and realised the big opportunities we had, greater and more effective work to be done. The paper dealt with the Conference which was to take place in October, and he thought he could, with the fullest confidence, assure Sir Edward Davson and the audience that although it might be called an Imperial Conference and that naturally the Dominions would occupy a very considerable portion of the proceedings, the Colonies and Protectorates would be very adequately and fully safeguarded and that their development and the part which they took in the Empire were regarded as of paramount importance.

The country had had an opportunity of knowing the work which had been accomplished by the visit paid to the West Indies by a previous Parliamentary Secretary, Mr. Edward Wood, accompanied by Mr. Ormsby-Gore. That work was of very material benefit, not only to the West Indies itself, but to the Colonial Office. He had stated the other day that personal interviews and communications were probably worth dozens of despatches and telegrams, and he was glad that there were present that afternoon so many who were engaged in Colonial administration, and he hoped they would favour the meeting with their views. He welcomed those gentlemen, who were doing so much in various parts of the Empire to carry on the great story and tradition. The Under-Secretary of State, Mr. Ormsby-Gore, towards the end of this year, would proceed to West Africa and by personal interview make himself, and thereby the Office he represented, fully acquainted with the conditions there. He hoped Mr. Ormsby-Gore would be able to assure the West African Colonies that the Colonial Office was not quite so remote as some people might think. He had also said recently on a public occasion, and he wished to repeat it now, that as long as the present administration at the Colonial Office was continued it was intended emphatically to put the fullest confidence in the men on the spot, who were carrying on a great work. The Colonial Office had the fullest confidence in their ability, judgment, loyalty and devotion to their duties, and he trusted they would always regard him and his advisers at the Colonial Office as friends. The Colonial Office was not anxious to interfere with them in their work, but desired to see the utmost possible co-operation. He could only wish that either the year was longer, or that Parliamentary life was less strenuous, so that they might be able to take extended trips throughout the Empire; he was afraid that under conditions of modern political and Parliamentary life, that happy state of affairs could only be longed for and not realised. If, however, that hope could not be gratified, fortunately there were those who like Sir Edward Davson were able to bring to their notice the history, needs and anticipations of the various portions of the Empire. The paper had been a useful and valuable one, and in making preparations for the holding of the Imperial and Economic Conference in October, he should undoubtedly see that the considerations that had been put forward that afternoon received the fullest consideration.

SIR HUGH CLIFFORD, G.C.M.G. (Governor of Nigeria) wished to add his congratulations to those that had already been expressed to his old friend, Sir Edward Davson, for his most interesting paper. It was going back a good many years since Sir Edward and he—then without any embarrassing handles to their names—foregathered in the West Indies, and he had been watching Sir Edward's career in connexion with those Colonies with great interest for a considerable period, but from a more remote portion of the Empire. It was a little difficult in these days for anyone still in harness like himself to speak of subjects such as those mentioned in the paper. Convinced as they were of the sympathetic treatment which to-day could be obtained from the Secretary of State, the Under-Secretary of State, and the Departmental Officers of the Colonial Office, it still remained a matter of some embarrassment to express opinions on subjects of this kind outside the office, and opinions not committed merely to the pages of a confidential despatch. Also, at the present time Colonial Governors, like other people, found it necessary in some degree to specialise, and for the last ten years his service had been exclusively in West African Colonies. There, the economic position had been rather precarious since the War. It might be said that they were not in a position to bargain with anybody because they had only a single customer, their produce going to a single market. London, Manchester and Liverpool, especially Liverpool, were the three centres in this country which dealt with West Africa. The whole of the produce was to-day shipped to Liverpool, even though some of it was subsequently transhipped to various ports of Europe. When, on the recommendation of Sir Arthur Steel-Maitland's Committee, a special differential duty was for a time imposed upon exports of palm kernels from West Africa to any port outside the British Empire, considerable trouble was caused in this

country, and having regard to the manner in which that duty operated, he, who individually never happened to have been a supporter of that policy, would hesitate very much to suggest to his Grace or to Mr. Ormsby-Gore that it would be advisable to reconsider the repeal of that particular measure. That was the only instance, in recent times, of any attempt to give a preferential advantage to this country and to the Empire at the expense of the West African producer, and those who were familiar with that experience would not, he thought, encourage the Economic Conference to reconsider the policy that was at that time adopted and subsequently, amid acclamation, discarded. So far as the Conference was concerned, he feared the West African Colonies were hardly in a position to make any offer to the rest of the Empire which would be worth the consideration of either the Home Government or the Dominions.

The Master of Elibank said the paper had presented a picture which could not but appeal to all who had dwelt in different parts of the Empire or who took an interest in the Empire from this country. He had been particularly interested in the suggestion that the Crown Colonies and Dependencies should be represented in the Imperial Economic Conference in October. He was not sure from the Chairman's remarks whether it was intended that that should be so or not, but he would suggest that an Economic Conference would be a very different proposition from an Imperial Conference, which dealt principally with Dominion affairs. It would be of the greatest advantage to representatives of the Dominions to be able to confer at first-hand with representatives of the Crown Colonies who understood intimately the conditions that existed there and the circumstances in which the people who lived there were placed. The Economic Conference would be called together to consider in the main questions of inter-preferential arrangements. He had the privilege, some 14 years ago, of taking a part in the drawing up of a preferential agreement between Canada and the West Indies; he believed that was the only preferential arrangement between a Dominion and Colony which existed to-day. If the opportunity were given for representatives of the Crown Colonies, the Dominion Premiers and Colonial representatives to consult together, he thought the greatest good would result. He asked his Grace to consider whether he could favour the recommendation which had been made by Sir Edward Davson.

There was one very important preference which could be conferred in these days with advantage to the Dominions and the Colonies and that was in connexion with sugar. He hoped that the Conference would consider the question of keying the position in connexion with preference. It was important that any preference granted by this country should be granted for a term of years. Just as Canada and the West Indies had a preferential agreement for ten years, he believed that this country ought to enter into preferential agreements with the Colonies for a term of years likewise. It was no good going to the capitalist and asking him to put money into sugar for instance, unless he knew that what was going to be granted in the way of preference would be granted, not for one year, but continued for a number of years. He would further suggest that just as this country was accustomed to enter into trade arrangements with foreign countries, and just as the Secretary of State for Foreign Affairs, with the consent of the Chancellor of the Exchequer, was able to enter into a trade arrangement, not to increase or decrease a duty in connexion with a foreign article for a definite term of years so ought it all the more to be in the power of the Secretary of State for the Colonies, with the co-operation and consent of the Chancellor of the Exchequer, likewise to enter into trade arrangements for a term of years with the Dominions and the Colonies. There were one or two other ways in which preference could be granted. For instance, there was the case of stamp duties. It was quite possible in the case of loans to the Dominions and to the Crown Colonies that a preference might be granted in stamp duties, and the same might be done in connexion with companies floated for the purpose of the development of the Colonies. He also believed that it was not asking too much that subsidies should be granted where it was not possible to create a steamship service otherwise. Although it might not be possible to grant the Dominions all the preference they required, it might be possible to make a return in one way or another for what they were giving us to-day. At the same time the Dominions and Colonies must remember that we were conferring great and direct benefit upon them by affording them protection by the Navy and through the money market here, *e.g.*, the Trust Securities Acts, under which Colonial securities were made gilt-edged securities. He could not go the whole way with the author when he said that loans raised in this country should be spent entirely here; but as far as possible this should be done. The same question arose in the House of Commons last year in connexion with the Indian Loan. It was then urged that the whole of the Indian Loan should be spent in this country, but it was pointed out that a certain amount must be spent locally.

Sir Robert T. Coryndon, K.C.M.G. (Governor of Kenya) said that Uganda produced this year 80,000 bales of good-class cotton. Kenya in November and December of last year from one corner of the native reserves produced native grain, maize, at the rate of over 100 tons a day. That figure was exceptional, but both those figures indicated what could easily be done by harnessing the various forces which were at disposal on both sides of the Continent. In the East African Dependencies there were ten million of willing workers depending only on education, sympathy and

encouragement, working side by side with the European settlers in the development of produce. From the capital and energy thrown into the country the general result in benefit to this country would be enormous. The native of Africa was not only a taxpayer and labourer, but a potential contributor to the Customs revenue, and, when prosperous, could be a great consumer of the out-turn of British mills and factories. All the enormous energies largely latent, which exist there, before they could be used must be dealt with in terms of the local problems of transportation and markets, and it was very largely the duty of the local Governors concerned, together with the interest of England, to visualise the whole of the problems with the African vision, because without that vision the people would perish. The African vision should be shared, not by the people in the Colony alone, but by the headquarters in England, not by one Department, but by several. It was their duty not only to control the Colonies, but to push them, not only to co-ordinate the efforts of those working on the spot, but to stimulate them, and it was one of the most important factors to produce and assist by rendering as easy as possible the raising of loans and the development of methods by which the obligations imposed upon the Colonies could be made as easy as possible. The Economic Conference would, no doubt, examine all those matters, not only from the point of view of small local obligations, but the much broader issues which the author had dealt with and that, together with the sympathy and stimulus which the Chairman had spoken of and which they in the Colonies most cordially welcomed, would produce, he believed, a great development in the Colonies, which were really a branch business of the Empire.

Mr. Richard Jebb said he was in agreement with the address, but wished to put forward one or two points to supplement what had been said. With regard to the organisation of the Conference, it seemed to him rather a pity that each Conference appeared to the public to be the first of its kind; if there was an Imperial Conference in the present year, the attitude of the newspaper public was that there had never been one before; that it was a new venture and great enterprise on the part of the Government of the day. It would be an advantage in every way if some sense of continuity could be given, so that the public could be brought to feel that the Conferences were not spasmodic, but part of a regular system being steadily worked out. He was rather sorry that the old resolutions with regard to Imperial policy before the War were not used again. In 1907 the Imperial Conference passed a resolution defining its own constitution and, incidentally, making provision for a subsidiary conference. For several years, up to the War, ancillary conferences took place under this resolution, each being called a subsidiary conference on something or other. If one thought of the forthcoming Economic Conference as a subsidiary conference on economic relations, the whole question of its status was decided at once. Anyone who desired to know the status of the persons attending it could find out if it was under the resolution of 1907, and writers and speakers about it were compelled to think of it as a conference which was only one of a series called in pursuance of a policy already accepted. The author had referred to the need of continuity of policy. There had been more continuity of policy than the general public or newspapers had realised. The subjects for discussion had been already announced, all relating to matters which had been fully discussed at the Imperial Conferences in 1917, 1918 and 1921, conferences which were probably already forgotten. Before coming to the present meeting he had glanced through the reports and had discovered that the number of resolutions relating to commerce within the Empire passed in those three conferences totalled 26. The forthcoming Conference was plainly continuing the work of the other conferences and, to that extent, there was continuity. It would be extremely useful from the point of view of the journalist and the general public to have an official statement prepared by the Colonial Office and circulated, drawing attention to the resolutions of the three preceding conferences and giving a detailed summary of what had been done since to give effect to those resolutions. A statement such as that would show that the conferences were all successive incidents in a policy which was being pushed on steadily from year to year. With regard to preference, he entirely agreed with Sir Hugh Clifford. Although he himself had always been a consistent advocate of Imperial preference, nevertheless there were limits, and a system of preference might begin to conflict with the duties this country had as Trustee towards subject peoples. He did not know whether it would be possible to adopt as a principle that the granting of preference in any one part of the Empire should depend on the assent of some representative local element in the legislature, if there was a legislature, and that it should not be imposed by force, as it were, from the Imperial authorities. Before the War preference was regarded as one of several ways of developing the Empire economically, other ways being steamship communications, cable communications, emigration and so on. By this time he thought it had become clear that all those questions hung together; that it was not possible to have a policy of fiscal preference without taking into consideration shipping arrangements, telegraphs, migration, and so on. It used to be said in some cases that preferences already in existence were being offset by the rebates which the shipping companies granted to foreign competitors. It was now generally realised that all those things were interdependent. There was a feeling of confidence in the paper which was justifiable. Wherever one went one found a confidence that some big push was going to be made in the direction of co-operation within the Empire for the mutual benefit of all the peoples, and that was going to be

a great help in getting things done when the actual conference took place.

BRIGADIER-GENERAL SIR GORDON GUGGISBERG, K.C.M.G., D.S.O., R.E. (Governor of the Gold Coast) said that in a large part of England there was some misapprehension as to the exact locality of a most important unit of the British Empire, namely, the Gold Coast. As Governor of the Gold Coast he welcomed the idea of the Economic Conference because he was sure it would result in nothing but good, if it was careful to avoid one rather thorny point. The native of the Gold Coast was very much alarmed by the words, "development" and "economic development." The native of West Africa had always been very much on his guard against his land being taken. Needless to say, no attempt had been made to do so; although it had perhaps appeared on some occasions as if we had that in mind. The native was seriously alarmed about such things as Empire development, and if the Economic Conference was not tactful in publishing its reports and making it quite clear that what it was after was to help the people to develop their own land to the best economic advantage, there would be trouble in getting them to see the right course to take. The chief need on the Gold Coast, which he hoped would be met by the Conference, was the institution of some Advisory Board at home which would inform the country of the commercial value of the raw products and state what new products might be tried. If that was made a function of the Conference, and some such body could be evolved, it would be of the greatest value. His personal opinion, after three or four years of administration, was that it was necessary to establish bodies in England to advise the Gold Coast on various matters, such as agriculture, mining, timber and many other things. The advice given by various bodies was all very admirable and had good aims, but he thought the efficiency and the value of their advice would be enormously increased if the Economic Conference could evolve some way of dovetailing their efforts and getting a little co-operation. The author had mentioned a development programme for each country. Practically all Local Governments had a scheme of their own and were trying to work on a definite agricultural programme for the production of raw materials. The Local Governments would probably receive great assistance from an Advisory Board, who could say what should be done and the value of those indigenous products which were now being grown in small quantities. But Governors had to base their policy for agricultural development on many local circumstances. There was first the characteristics of the race, their stage of development and evolution from primitive to civilised races; secondly, the stage of efficiency which communications—an all-important thing in trade—had reached. Some countries were better off than others. Thirdly, they had also to consider the main product of the time. A very good example of that was the Gold Coast, where there was produced about 600 tons of cocoa a day and some 80,000 or 90,000 tons of Manganese, amongst other things in a year. It was sad to think that those industries occupied practically the whole of the population of just over two million, whereas the country had an enormous number of raw products of potential commercial value. The author had mentioned that one of the chief things was to increase the health of the population so as to improve their physique and reduce infant mortality. With regard to preference, when on the Gold Coast they had a visit from the Canadian Commissioner who wanted them to adopt preference, the Government asked what were they going to make or lose by it. The Commissioner said: "I think you will probably lose to begin with." The answer was: "If we are to lose to begin with, we are not for preference." That, he thought, was the view which was going to be taken by most Colonies. The natives had an instinctive dread of preference. Sir Hugh Clifford had mentioned the effect of the palm kernel ordinance. He thought Sir Hugh would agree with him that the effect in West Africa was probably greater than it was in England. The natives hated it, and he had to make use of his official majority in the Legislative Council, a thing he very much disliked doing, in getting the ordinance through. With regard to the composition of the Conference, it would be of the utmost value for personal contact to be established between representatives of the Crown Colonies and of the Dominions, but he had the very greatest confidence in leaving that matter in the hands of the Duke of Devonshire and the Colonial Office, because he thought there would be a very great opportunity in 1924, during the British Empire Exhibition, of getting into touch with the Dominions and finding out what they could give and what they could take. There had been a system of preferences on the Gold Coast, because whenever a Loan had been raised to build a railway or harbour, all the materials had to be obtained from the Mother Country. They were glad to do that because they were very patriotic, but they had had to pay for it, and that rather looked like a system of preference.

MR. A. R. SLATER, C.M.G., C.B.E. (Governor of Sierra Leone) said he only wished to make two points. Firstly, speaking on behalf of his small corner of the Empire, he should be doing less than his duty to its people if he allowed the author's description of its size to pass unchallenged. Sierra Leone of to-day represented much more than the mere "colony" clustering round Freetown. There were behind that Colony 27 million square miles of good hinterland, and it was on that Protectorate that the trade of Sierra Leone both external and internal, depended. Therefore, the point was one of some importance in connexion with the Economic Conference. Secondly, he should like to endorse what his fellow Governors

had said about preference and to emphasise the fact that, as far as he knew, the native members, certainly of two of the Legislative Councils in West Africa, were distrustful of preferences. That fact might be deplored, but it was a fact which he thought should be borne in mind because it would be generally agreed that if any system of preference was to be carried throughout the Empire it should be carried with the assent and goodwill of the native members. For himself he thought the Conference would be on safe ground if, in any system adopted, the wise words of Sir Frederick Lugard were remembered: "The tropics can only be successfully developed if the interests of the controlling power are identical with the natives of the country and if it seeks no individual advantage and imposes no restriction for its own benefit."

The Hon. W. Ormsby-Gore, M.P. (Under-Secretary of State for the Colonies), in proposing a vote of thanks to the author for his paper and to the Duke of Devonshire for taking the chair, said the afternoon had been an extremely profitable and interesting one, suggestive and helpful to all who had to face the problems of Empire. Nothing had struck him so much in the course of the discussion as the different terminology which was used in different parts of the world. The word "Preference" had an entirely different meaning in the West Indies from what it had in West Africa, and similarly, the word "development" had a different connotation in those two parts of the world. The great difficulty of any representation of the Crown Colonies and Protectorates in Conferences where the Dominions were also present—other than by the Colonial Office—was the enormous variety of the local idiosyncracies of the nearly fifty Crown Colonies or Protectorate Governments. He had only to go to the West Indies to learn that it did not do to talk very big about "Federation," but provided it was not called "Federation" one could talk about any of the things involved in what might be called Federation. Similarly there were things which might properly be described as Preference which might be discussed between West Africa and the Colonies, provided it was not called by that name. The whole problem of bringing the Crown Colonies and Protectorates into the counsels of Empire, particularly on economic questions, was very difficult and, at present, had not found adequate solution. There was a growing recognition on the part of the Dominions of the significance and importance of the non-self-governed parts of the Empire. One had to recognise, however, that there were causes for the relations between Fiji and Australia, which were not what they might be, certainly from the point of view of Fiji. Those problems were beginning to come up, and as the Master of Elibank had pointed out, the admirable interest which Canada had shown in recent years in communications in shipping with the West Indies and in preference, was a step in the right direction. Australia and New Zealand were beginning to have little Empires of their own in their mandated islands, which were opening their horizon, and there was no doubt that East Africa and the Union of South Africa had considerable points of interest in common. All those problems were really in their infancy, were fascinating and were opening up tremendous potentialities. The Economic Conference ought to be merely a preliminary to the great British Empire Exhibition next year, which would do quite as much as any meeting of statesmen to show the dependent parts of the Empire in their relation to the self-governing white inhabitant parts of the Empire. The paper would help the Colonial Office very materially in beginning to think out some of those problems. The Secretary of State and himself had had a first meeting on the previous day to go into the Economic Conference questions, and no doubt those meetings would become more frequent as time went on and it would be necessary to go in detail into all the many problems. It was of the greatest possible assistance to have, from one who knew the problems like the author, so admirable a lecture showing a wide grasp of the Colonies as a whole. The great belt of tropical charges which this country had was growing in importance in connexion with the maintenance of the industries in this country and its position in the world as a whole, and the more that was realised by the public, the better.

The motion was carried unanimously.

Sir Edward Davson, in returning thanks, tendered an apology to Mr. Slater for the unmerited slight cast on his Colony in relation to size. In the early part of his paper he had thrown out a suggestion of a Colonial Conference presided over by the Secretary of State and attended by the various Governors. He really thought that Conference had now taken place, because that afternoon there had been present the Secretary of State and the Governors of most of the important Colonies, giving their views, which had been of very great interest.

The meeting then terminated.

GENERAL NOTE.

Gold Deposits in Germany.—Gold deposits were reported recently as found in the Eder River near Korbach, in the former small "Fuerstentum" Waldeck, just east of Westphalia. Investigation proved the existence of some gold veins and showed that a ton of earth in the mountains near Korbach produced 44 grammes of fine gold. As the average gold content of this amount of earth is said to be only 10 grammes, the Korbach finds are considered promising and mines are being established. This, writes the United States Commercial Attaché in Berlin, is said to be the first time in 300 years that the development of gold mines in Germany has been discussed.

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FRIDAY, AUGUST 3, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

PROCEEDINGS OF THE SOCIETY.

INDIAN SECTION.

FRIDAY, JUNE 1ST, 1923.

SIR CHARLES CAMPBELL MCLEOD in the Chair.

The paper read was:

THE PARTICIPATION OF INDIA AND BURMA IN THE BRITISH EMPIRE EXHIBITION, 1924.

BY AUSTIN KENDALL, I.C.S., retd., Secretary, Indian Advisory Committee.

In early April next year there will open at Wembley the largest Exhibition which has been held in England—the British Empire Exhibition. The Glasgow Exhibition held at the beginning of the present century stands out as an example of a great Exhibition successfully run with a healthy balance on the right side; and it will not be the fault of the British Empire Exhibition Authorities if the British Empire Exhibition fails to show similar results.

It will, I think, be well to say a few words about this great Exhibition before coming to the sections assigned to India and Burma respectively; for Burma, as I will show you, has decided to have its own separate building, in grounds separately allotted to it.

The idea of an Empire Exhibition was mooted in 1912 by Lord Strathcona, but the Great War supervened; and all arrangements had to be held over. When it was taken up again, in 1919, it was taken up by an organisation which does not seem to have commanded very great confidence; and there was, I understand, a danger of the whole project falling through. It came to be recognised that, without the assistance of the British Government, direct or indirect, success could not be anticipated; and that assistance could only be obtained by an entire reorganisation of the management. The Board of Trade, under the Presidency of Sir Robert Horne, then passed through the House of Commons, a Bill which provided for a Government guarantee of £100,000 on condition that other guarantors, up to a minimum of half-a-million pounds, were forthcoming. To further this Guarantee Fund, H.R.H. the Prince of Wales, before he sailed for India in October, 1921, held a meeting at the Mansion House; and by January, 1923, guarantees to the extent of a million pounds had been obtained and lodged at Lloyds Bank; and at the present time guarantees have come in to the extent of upwards of 1¼ million pounds. On the strength of these guarantees, Lloyds Bank is advancing the money with which Wembley Park has been obtained, and with which the grounds are being laid out, and the requisite enormous buildings erected.

I have been asked repeatedly why the Exhibition is being held so far out of London as Wembley, and why it is not housed at the White City, where the remains of so many buildings are standing, and which has become so associated in the minds of Londoners with Exhibitions.

The answer is two-fold: Wembley is not so far out of London: and the Exhibition would have been housed at the White City if that area could have been obtained at anything approaching a reasonable sum.

As to the accessibility of Wembley. It is possible to leave Victoria Station in a motor car, visit Wembley, have a look at the Stadium and the buildings under erection, and be back at Victoria in under 1½ hours.

Wembley is not far beyond Willesden, straight down the Harrow Road; and the high road from Willesden to the North Entrance of the Exhibition, two miles long, is to be 60 feet broad. There will be numerous special services of omnibuses at all hours; while both the Metropolitan and the Great Central Railways have not only greatly enlarged Wembley Park and Wembley Hill Stations respectively, but the latter company has constructed a new loop line into the Exhibition grounds, which incidentally will drop its passengers at a platform

immediately behind our Indian Building. Fifty-seven thousand passengers an hour will be dealt with by these two companies, not counting excursion traffic from the Provinces.

As a further proof of the accessibility of Wembley, I may remind you that on the occasion of the Cup Tie Final, the railway and omnibus authorities brought to Wembley in a few hours more than double the number of men comprised in the first Expeditionary Force which was landed in France.

The area of the Exhibition is 216 acres, and the part covered by buildings will be upwards of two million square feet, 700,000 square feet of which will be occupied by Indian, Dominion and Colonial buildings. This area is more than double that covered by the Franco-British Exhibition, while India alone has a space as large as all the Dominions and Colonies had at that Exhibition. To put it in a way which will perhaps appeal to you more directly, if the Exhibition area could be lifted and laid down in London, it would cover an area extending in its length from St. James's Square and Marlborough House to the far side of Waterloo Bridge, and in its breadth from just south of the Horse Guards in Whitehall almost to the Palace Theatre in Shaftesbury Avenue.

Finally, I may say that there is an astonishing amount of work being done at Wembley. The Industrial and Machinery Halls, the Palace of Industry and the Palace of Engineering, I think they now call them, the latter of which has 6½ times the capacity of Trafalgar Square, are to be completed by August, and there are well over 2,000 men a day at work.

The Exhibition administration in general, and the General Manager in particular, have been subjected to much criticism from time to time in a certain section of the Press ever since the alteration took place in 1919; and that criticism has found its way into the Indian and Colonial papers, with the result that doubts have been expressed in many quarters as to the solvency of the undertaking and as to the efficiency of the administration. I have already referred to the adequacy of the guarantees. I may be permitted to add a few words as to the present organisation. The Exhibition is run, if I may use the word, by a Standing Administrative Council or Board, which is, I believe, always sitting; a Management Committee, which meets weekly; and an Executive Council, which meets quarterly. The Standing Administrative Council or Board consists of Sir James Stevenson, who has been called one of the most hardworked unpaid servants of the State, as Chairman, Sir Travers Clarke, who is well known as one of the greatest authorities on transport, and who was, till lately, Q.M.G. at the War Office, as Deputy Chairman, Sir Charles McLeod, who is also Chairman of the Finance Committee, Sir James Allen, High Commissioner for New Zealand, who represents the High Commissioners, and Sir Henry McMahon, who won his laurels in India, and who is Chairman of the Management Committee. Such names are surely a guarantee that the Exhibition is in good hands.

The Memorandum of Association of the British Empire Exhibition Corporation specially provides that any balance, after the settlement of liabilities, shall be devoted to public objects, charitable or otherwise, to be determined with the approval of the Board of Trade; and our Chairman (Sir C. McLeod), addressing a meeting convened by the late Sir William Meyer, of firms and persons interested in India, said that before he associated himself with the Exhibition in any way he made perfectly certain that no person living was going to get anything out of it in the way of profit; that the Exhibition was to be run for the Empire and not for profit.

That is what I want you to remember, for the Empire and not for profit. The day is closed when we can merely talk about Empire; it is time to do some spade work and achieve Empire. We varied units, scattered over the whole world, thousands of miles from the Old Country, want to weld ourselves into one composite body, independent if need be of the outsider. There is nothing produced but can be utilised somewhere: there is nothing needed but can be procured somewhere; and it is the main object of this Exhibition to show that there is nothing we need which cannot be produced, nothing we ask for which cannot be supplied, somewhere in our great Empire. It is surely a grand project—a project which justifies, nay rather demands, our co-operation.

And now we approach what is the title of my paper, the participation of India and Burma in this great Exhibition.

India, with its area of nearly two million square miles, and a population of about one-fifth of the total population of the earth, has participated in many Exhibitions

before, from that of 1851, in which she was allotted 24,000 sq. ft. She exhibited in Paris in 1867, 1878 and 1889, in Philadelphia in 1876 and in Amsterdam in 1883, where she provided a great attraction by free distribution of cups of tea. Her exhibit at the Colonial and Indian Exhibition in 1886 covered 103,000 sq. ft., and of this exhibit it was said that it was hardly possible to over estimate its value to the British Empire at large. The unprecedented success of the Indian section was in no small measure attributable to the public spirited and loyal munificence of the Indian Princes, whose support, it was reported, was the making of the Exhibition.

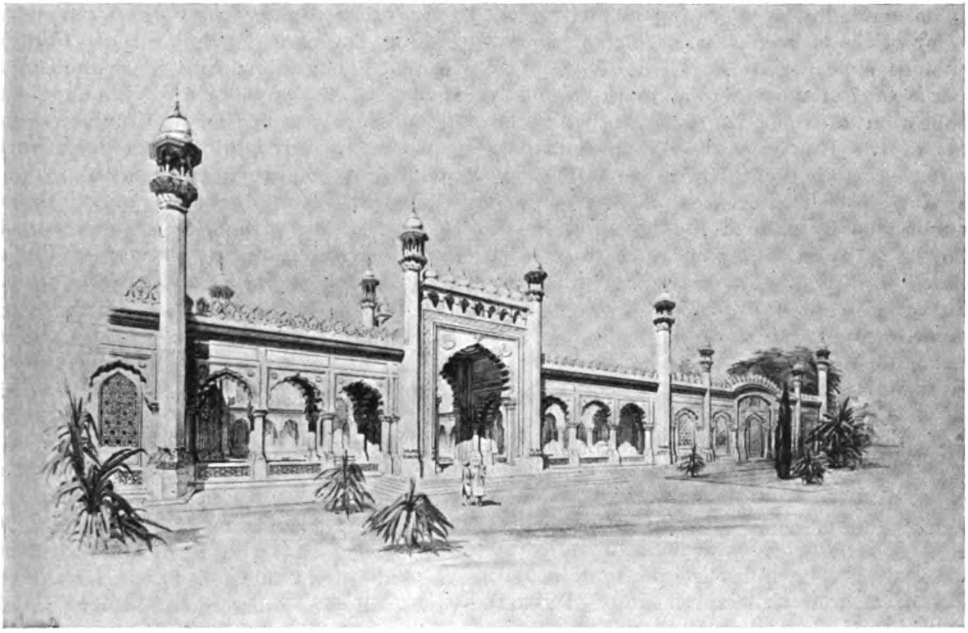

FIG. 1.—Main Façade, showing Court within.

The India that will be exhibiting at Wembley in 1924 is a very different thing from the India of 1851. India in 1851 was an India administered by that wonderful company of merchants trading to the East Indies, the Honourable East India Company, with a civil service appointed by nomination and trained at Haileybury College. There were very few miles of railway, and most of the travelling was done in that most cumbersome and comfortless conveyance, the dak-gari. There were no canals; and when a drought befell, famine could rage unchecked and take its toll of thousands of the poor and unfit. The head of that very fine race, the Mahrattas, was on his death-bed and our army was just recovering from the wounds and struggles of the two Sikh wars which had finally added the Punjab to the area administered by the Company. There were quite a number of Indians even then assisting in the government of the land. She was looked upon as a land from which came drugs, dyes, and luxuries.

But India of 1923 is an India entering upon a new era.

I have purposely avoided wearying you with anything in the nature of elaborate statistics; but I have here a few figures which you may find interesting as showing the advance of India since the beginning of the present century. Her Land Revenue has risen from 55 million pounds to 83 million pounds; the number of miles of railway has increased from 15 thousand to 49 thousand, while the number of passengers carried has increased from 111 millions to 437 millions. The number of acres under irrigation from canals rose in the same period from 11 millions to 23 millions, and there are schemes in progress at the present time which will enable a very large additional area to become to some extent independent of the droughts which periodically occur. From the beginning of this century the number of cotton mills

has increased from 125 to 263, and the number of jute mills from 26 to 76. The amount of coal produced has risen from 2 million to 18 million tons. As to India's sea-borne trade, the freight tonnage has risen from 22½ millions to 87 millions: the exports rose from 60 to 210 millions, while imports rose from 43½ to 155 millions.

To quote from an American writer:—"India has been touched by the magic wand and has been aroused from the lethargy which for so long has acted as a damper to advancement." As the number increased of clever and enthusiastic Indians, ready and fit to take a place in the administration, and to tackle the many and complex problems which are continually arising, so were advances made in the reforming of the internal policy of the Government. On this gradual advance supervened the Great War. The people of India came to a more complete realisation of their comradeship with the rest of the Empire; their representatives were called to join with the other Dominions in Imperial Conferences; their troops fought side by side with their brothers of the Empire on many fronts; and this association in arms, this opportunity to display in dramatic fashion the practical importance of India to the Empire, gave a sudden acceleration to the pace of both political and industrial advancement. "The old order changeth, giving place to new" is a trite and well-known saying, but to the doubts of the sceptic the old Latin verse affords a more appropriate answer, particularly in its conclusion, "Tempora mutantur, *et nos mutamur in illis*." Both politically and industrially India is adapting herself, and we, as well-wishers and many of us old servants of India, will adapt ourselves, to the altered circumstances, circumstances, be it remembered, which are not the creature of the autocratic will of some one Secretary of State, but which are the natural outgrowth of the aspirations, which we, by our set policy have created and which have been justly stimulated by the glorious Indian traditions of 1914 to 1918.

It is this new India which will come before you next year, and which will show the Empire how she has advanced in material prosperity, how great and how much more varied her resources are, and how it will be to the advantage of the Empire more than ever before, to deal with her, both by taking the goods she is able to supply in ever-increasing variety, and by confidently exporting to her the various commodities of which she stands in need.

India has decided to participate in the Exhibition with two principal objects in view. From the point of view of her commerce, she is convinced of the value of an Exhibition of this nature in order to demonstrate what she can produce. India has for a very long time been noted for certain classes of products, for art work and craftsmanship, which are peculiarly her own. In this sphere she can do a great deal more in the direction of bringing her products to the notice of the world, and of the Empire in particular. But she wishes to go further than this, and to demonstrate that in respect of the greater industries she is progressing rapidly to a place among the leading nations of the world. She has secured recognition from the Council of the League of Nations as one of the eight chief industrial states of the world, and in representation at the Exhibition she looks for an opportunity of proving her status.

She realises that she has much to gain by association with other countries of the Empire in the scientific study of disease, and of problems of housing and sanitation.

In a country of the size of India, one which still has very far to go in the process of industrialisation, it is obviously no easy matter to organise an Exhibition which will show the best that the country as a whole can produce in the best possible way. In spite of this, and in spite of the fact that the invitation to participate came at a time of acute financial stringency, it is noteworthy that the Legislative Assembly decided in favour of participation with practically no dissentient voice. It has to be remembered that the Reformed Constitution made a very great break away from past traditions, and that the different Provinces now enjoy a very much larger measure of independence than they ever enjoyed before—particularly in the matter of expenditure from their revenues. Consequently, in order to enable an Exhibition to be organised on an all-India basis, it has been necessary to obtain the approval not only of the Executive authorities in the major Provincial Governments, but also of the Legislative Council in each Province, to the necessary outlay. The Central Government are sanctioning expenditure in the neighbourhood of £200,000; while the Legislatures of the participating Provinces have allotted in all £125,000 beyond this. It is probable

that some portion of this will be recovered by rent from stall-holders and in other ways, but no conditions have been attached; and the magnitude of the contributions afford an earnest of the definite intention of the Reformed Government that India's display shall form a worthy part of a British Empire Exhibition.

In judging of the difficulties involved in the attempt to organise a comprehensive exhibit, not only must the vast extent of British India and the Indian States, and the great distances which separate one part from another be borne in mind, but also the fact that tho whole exhibit has to be transported thousands of miles by sea. Compared with the size of India, the space taken by the Indian Government is small, and obviously a great deal of compression will be necessary.

The organisation of the exhibits from India the Government of India have kept in their own hands; and Diwan Bahadur Vijayaraghava Charya, the Exhibition Commissioner, has been very busy for some months past. He came to England for a short time last winter to discuss preliminaries, and he sailed again from Bombay only last Saturday. Consequently I have been unable to give you as much detail as I should have wished.

The general principle which the organisers of the Indian exhibit will attempt to follow will be a central collection displaying those industries which are of major importance and which represent India as a whole, rather than any one province or tract, while the smaller arts and crafts will be displayed in the Provincial Courts.

When Major Belcher read his admirable paper before this Society some months ago on the Dominion and Colonial connexion with next year's exhibition, the First Lord of the Admiralty, who did this Society the honour of taking the Chair, referred to the chief requisite of the Dominions as three M's: Men, Money, Markets—and I would apply the same three M's to India too. True it is that India has not the huge untouched acreage where Canada and Australia, e.g., can find happy homes and healthy work for any number of superfluous Britons, and so be adding continually to one of the chief assets of the Empire, the sturdy, big-hearted Colonist. But India does still want men from Home; as the proportion of Europeans to Indians in the administration of the country, political and economic, decreases, so will the opportunities and the responsibilities of that diminished proportion increase. Whether it be in the office, or in the counting-house,

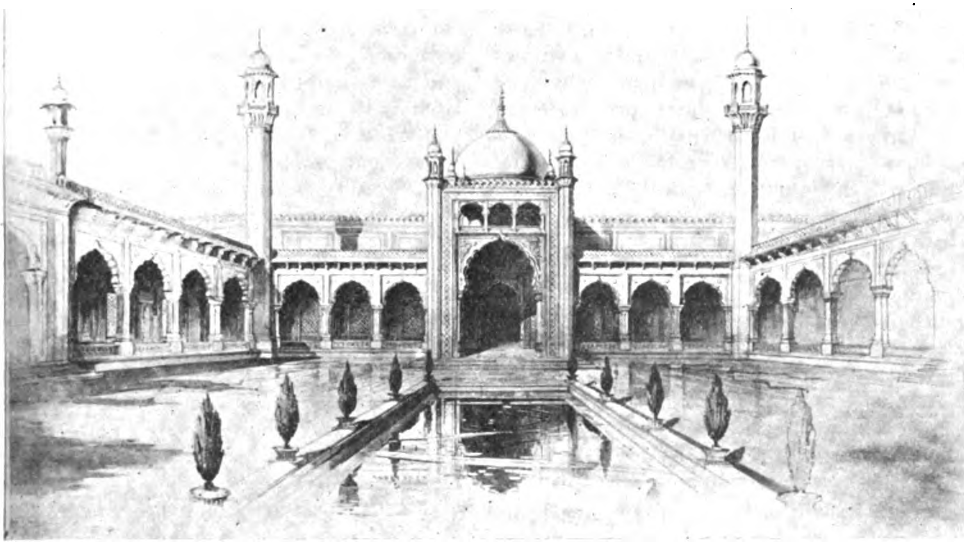

FIG. 2.—Main Entrance in Court, showing Colonnades and Minarets 110 feet high.

or in the factory, there will still be a call for men as good as, or better than, we have given to India in the past.

What is this new India going to show the Empire? I saw an article in an Indian paper deprecating enthusiasm over the Exhibition, which the writer said was a mere piece of commercial pageantry. Why, he said, make an exhibit of raw material which is well known, and of materials which already have good markets? The public in England, he continued, have plenty of admiration but no money to spare to buy the art wares of India. The writer, I fear, had no great knowledge of his country's resources, and he was imbued, I hope you will agree, with rather a parochial spirit? When all the countries of the Empire are coming together, and are dressing their shop windows, is India to remain behind? Are there no others to whom her raw materials are to be shown—no other markets to be found? If India can, at this Exhibition, show those others that she has what they need and can supply to them at a marketable price, then she will be deriving benefit from the Exhibition. Provide a cheap market and people will begin to buy, *and will go on buying.* An Indian friend of mine once brought me a Christmas card and, as he handed it to me, he said in what he thought the best of English, "You know, Sir, many others who are bringing you cards have bought them on the Mall." (The Mall is where the smarter shops are to be found.) "I bought mine in the chowk (the "Bazaar") they are much more damned cheap there!" And is that not, after all, the spirit of commerce?

Do you know that the boots supplied from Cawnpore in thousands to the Army during the Boer War were better and cheaper than those furnished by any other contractor? Do you know that when the late war broke out Cawnpore had a contract on hand for 80,000 pairs of boots for a Continental power, that, within a few months of the outbreak of war, Cawnpore sent home 15,000 complete sets of Artillery harness, and that 25,000 pairs of boots a week went to the Allies? Or again, is it news to you that most, if not all, the tents used in Palestine, in Egypt, and in Mesopotamia, came from that one little town on the Ganges, Cawnpore? Cawnpore, too, has very big contracts with the Government for boots, brushes, greatcoats, jerseys and other articles needed for the Army and the police. I may be excused for expatiating upon the capabilities of Cawnpore—I was stationed there many years and was more and more impressed with what it could do. And it does not stand alone.

Take timber again. Much has been said lately about Empire Forestry. In 1920 we imported 82 million pounds' worth of timber into Great Britain. There are miles upon miles of forests in India and Burma administered for the most part by one of the most efficient of the Indian Public services, the Forest Department; and the trade in timber, bamboos, and minor forest products, is capable of incalculable expansion. There are certain well-known timbers on the market; the greater number of species are little known. The market for these is gradually being expanded by the efforts of the Forest Research Institute, which is in this connexion making continual improvements in the present methods of seasoning the various species, and in the antiseptic processes of treating timbers to protect them against rapid decay and white ant attack. In this rapid sketch I have purposely refrained from wearying you with statistics, but the figures of outturn of timber and bamboos are of interest to show how the trade is extending. In 1898 the outturn of timber was 52½ million cubic feet; in 1918 it had risen to 91½ million —an increase of 75%. Similarly the outturn of bamboos rose from 141 million to 153 million. A factory to produce 5,000 tons of paper per annum from bamboos has recently commenced operations in Calcutta, and a complete pulp and paper experimental factory is being equipped at the Forest Research Institute. Surveys have shown that stocks of Savannah and Bamboo grasses sufficient to produce *more than one-third* of the world's total consumption of paper pulp exist in India and Burma, and the Forest Department look confidently to a considerable export trade especially to the Far East and Australia.

An elaborate paper on "The Timbers of India and Burma," prepared by Mr. Alexander L. Howard, was read before this Society last year, when it was suggested that the Society might panel the room in which this meeting is held with Indian woods. I am afraid the seed fell upon barren ground? However, it is never too late; the Society may yet see what I may venture to call the error of its ways!

Some idea of the very large number of

forest by-products in India and Burma such as tanning and dyeing materials resins, and gums, and their value will be obtained from the exhibits which will be shown in the sections of the appropriate Provinces and in the Burma Building, and there is no space to detail them here. I may just mention two to which the Forest Department attach importance, resin and turpentine, 78 per cent. of which is at present produced in the U.S.A. In 1907, 76,000 cwts. of resin were imported into India and 5,000 locally produced. In 1922 imports of resin fell from 76 to 18,000 cwts. while local production rose from 5 to 82,000. In that latter year, 30,000 cwts. were exported. The turpentine figures are equally interesting. Imports fell from 225,000 gallons in 1907, to 90,000, including substitutes, in 1922, local production rising in the same period from 16,000 to 279,000, while a successful commencement has been made with its export.

There is a great future in the forest by-products, as these figures show.

Under the guiding hand of Mr. Alexander Howard, of Messrs. W. W. Howard Brothers, a special effort will be made to show what we can do with Indian woods. The offices of the P. and O. Banking Corporation have recently been fitted entirely in Indian wood at a considerably less cost, I am informed, than would have been incurred had other woods of a similar quality been used. The High Commissioner's Office, at 42 and 44, Grosvenor Gardens, has been fitted up from India; panelled walls, parquet floors, tables, chairs, bookcases, overmantles, al carried out by well-known firms, and entirely of Indian woods. These rooms, as well as a sample room of Art Wares upstairs, are open to the inspection of the public on any day. For house fittings, for railway carriages and stations, for fittings of ships and for yacht and boat building, India can, as she will show, supply wood in infinite variety and in more than sufficient quantity. One forest in the south of Burma alone is calculated to contain about 12 million tons of timber.

May I refer for one moment to the unfortunate repudiation, mainly in the piece-goods trade, which took place in the cold weather of 1920-21? The position was quite abnormal and is not likely to recur. 1920 opened at a time of feverish activity and apparent prosperity; but by the end of the year there was a wholesale curtailment in industry, with unemployment on an unprecedented scale. The internal disorganisation and financial chaos in Central Europe and the adverse exchange rates there ruling, brought about a serious diminution in the demand for Indian exports such as jute, cotton, hides and oilseeds, the backbone at that time of the export trade. The deflation of prices in the United States and United Kingdom not only checked fresh purchases, but entailed heavy losses on stocks of tea and

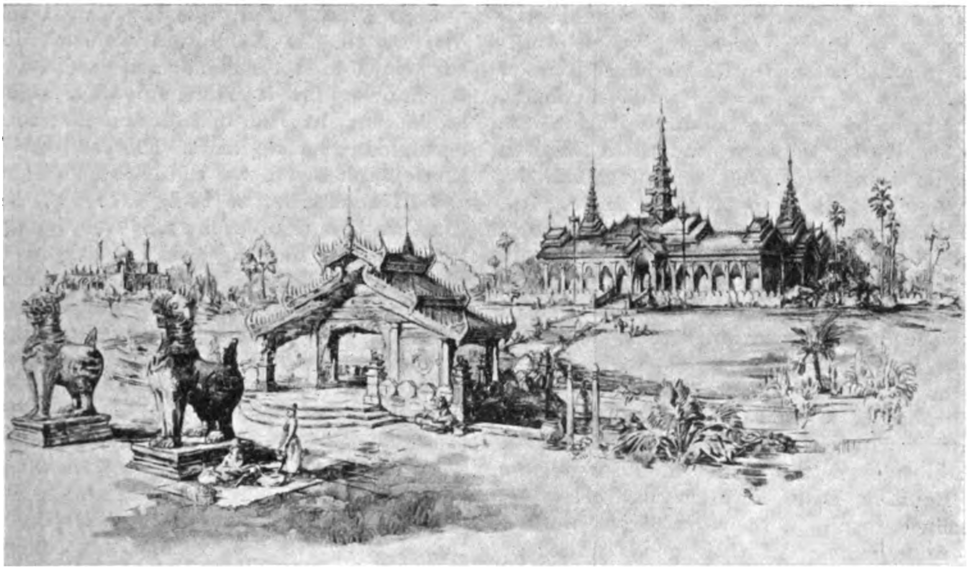

Fig. 3.—Burma Building, showing Grounds and Bridge Entrance.

other commodities. There was a marked falling off in Japan's consumption of Indian cotton. The isolation of Russia had begun. The monsoon, too, of 1920 was a poor one, and the country was suffering from many internal difficulties due to the results of war. All these causes contributed to bring about one of the most acute periods of economic depression experienced in India for very many years. Meanwhile, in the boom of 1919 and 1920, credit facilities had been rather recklessly given, and many Indian firms received credits more than their standing warranted; so that high priced goods arrived during 1920-21 in excessive quantities, representing the execution of orders placed during the height of the boom. The gross value of imports during the year was actually double the average of the five preceding years, resulting in a net balance of trade against India of 49 crores of rupees=£53 million pounds. The price of silver in London fell from 72*d.* to 30*d.* during the year, and there followed a collapse in exchange, which fell from 2*s.* 4*d.* on April 1st, 1920, to 1*s.* 3*d.* on March 7th, 1921. Importers and dealers had either not been able, or had been unwilling, to fix exchange at the time of placing orders, and so importers found themselves with extraordinarily heavy stocks of piece-goods, metal and hardware, bought at the top of the home market with exchange in the neighbourhood of 2s. and arriving in a stagnant market with exchange round about 1s. 3d. The result was that many Indian importers in Bombay, Delhi, Amritsar and elsewhere declined to accept their drafts, and refused to take delivery of their goods unless at an exchange rate of 2s. By the middle of 1921 repudiated and overdue drafts in India and Ceylon amounted to 30 million pounds. The banks adopted a most helpful and broad-minded attitude, and the crisis passed. A similar repudiation, and to an even greater extent, be it remembered, occurred in South America, China, Japan, and in fact in most countries with extensive commercial dealings.

I have thought it well to make a passing reference to these circumstances, which arose out of reckless credit to some extent on the one side, and out of almost despair on the other, and have tried to show what very abnormal conditions brought them into being. There is just as much honesty in their dealings with one another, I speak from experience, among Indian merchants, as there is at home.

A space in the main Fine Art Gallery of the Exhibition has been allotted to India. The space is limited; the material which might become available enormous. To assist in getting the best specimens of the various Schools together, and in making and arranging a selection to the best advantage, the High Commissioner has been fortunate enough to obtain the services of a very distinguished Committee. The result is to be a small and very choice collection of the best specimens of ancient and modern—I believe the correct adjectives are retrospective and contemporary—art.

The tea and cotton associations, as may be expected, will take care that their resources are adequately displayed. At the Amsterdam Exhibition in 1883, Indian tea, as I have said, was distributed free. Visitors to the Exhibition were at first suspicious of this unexpected generosity; but in a very few days the innovation became so popular that the distribution had to be restricted to certain hours. The Tea Association exhibit again was the backbone of the Indian Exhibition at Paris in 1899; and to those two Exhibitions may very greatly be attributed the enormous increase in the popularity of Indian tea on the Continent. We are not promised any such free distribution this time; but we shall only supply Indian tea in our Tea House, and we hope that the Indian Tea Association will indicate the sources of supply and will also supervise the brewing of the tea. It would be a sorry advertisement to supply tea which had been prepared with tepid water, or which had been stewing for 20 minutes. The sales of Indian tea have been regularly increasing, but there is room for expansion of the trade to any extent, both in the Dominions and elsewhere.

India is not going to have a Cinema Theatre of its own; but I hope it will be possible to illustrate its resources by films in the Exhibition Cinema Theatre, and by dioramas within our own Section. The great steel firm of Tata have a most interesting film of their work, showing its various phases, and I hope some of the other large industrial firms will see the advantage of following suit. In the case of Messrs. Tata I may mention that the Exhibition of 1924 is already bearing fruit. I have been able to put them in touch with Sir Robert McAlpine and Sons, who are proposing to take some supplies from them in connexion with their various contracts in the Exhibition

grounds; and some of the contractors for the Dominions buildings will, it is hoped, follow their example.

Bombay has grown enormously of recent years: and we are promised a most interesting exhibit from the Bombay Development Committee, showing how that growth has been dealt with on the latest lines appropriate to the climatic conditions.

The trade of a country is very fairly reflected in the activity of its ports; and when the main Indan ports set out to show something of their activities, as I hope they will at Wembley next year, the result will be something of an eye-opener to many whose ideas on Indian enterprise are very restricted. The sea-borne trade of India is said to be equal to that of Australia and Canada combined.

There will be a working exhibit of carpet-making, and we hope of other industries, too; but I have not been able to obtain from India any further details in time for this afternoon.

As to the Indian States, they are joining heart and soul in this Imperial project. Many and varied are the industries which have grown up in these States in recent years; and those industries will be displayed with the splendour which we have almost grown to expect from an Indian Prince, when he associates himself with any Imperial venture. Altogether the Indian States have been allotted one-sixth of the total available space; and we shall give them the heartiest welcome at this Exhibition, when we remember the whole-hearted patriotism with which they placed their utmost resources at our disposal during the Great War.

In the time at my disposal I have not been able to do more than touch upon a few of the resources of India. I have, so to speak, introduced you to India at Wembley, and I hope that you will make use of the introduction and will cultivate the acquaintanceship: I can assure you that it will repay you.

I will now turn for a few minutes to Burma. The arrangements for Burma are in the capable hands of Mr. Rodger, of the Imperial Forest Service, in England, and Mr. J. M. Symns, of the Indian Educational Service, in Burma. Both Mr. Rodger and the High Commissioner for India have Advisory Committees to assist them, comprising, I can say without exaggeration, the very pick of Indian administrators and business men, both British and Indian. My remarks on Burma are based upon a note given me by Mr. Rodger.

Since a beginning was made with the arrangements for the Exhibition, the inhabitants of the Province of Burma, both Burmans and Europeans, have made it very clear that they wanted their country to be represented separately from the rest of India. Burma is, from an administrative point of view, as much a part of India as is Bengal: but a very strong national feeling exists. Her religion, her thoughts, her manner of living, her cottage industries, are entirely different: and she has wisely decided to house her exhibits in a separate and characteristic building.

The Government of Burma appointed last year an influential unofficial Committee, representative of the various races, to take charge of all the arrangements for the Exhibition. On this Committee many Burmans and Indians are sitting, and they have taken the greatest possible interest in the work and have shown a keen appreciation of the probable benefits to the Province from an adequate representation of Burma at this Exhibition.

All the principal products of Burma will be shown by Government departments, by the firms, and by the Exhibition Committee. They include rice, timber, groundnuts, cotton, sesamun, tobacco, lead, tin, silver, wolfram, rubies, jade, amber, etc., and the Committee will show lacquer, silver-work, ivory, bronze and so on.

The grounds will be laid out in Burmese style; and it is hoped that the two Burmese elephants, which I see have lately arrived, and the Burmese peacocks which H. E. Sir Harcourt Butler has presented to the Zoological Gardens, will add to the picturesque nature of the surroundings.

A special effort will be made to expand the sale of Burma rice, which, owing perhaps to its inferior whiteness, is not in as great favour at present as highly polished Indian rice, although its nutritive properties are said to be greater.

The forests of Burma cover 150,000 sq. miles, with 2,000 Forest Officers in charge of them, and the revenue for the nine months ending March, 1921, was £1,100,000. The large timber firms and the Government Forest Department will show all the Burma timbers and other forest products in great variety, as this is a field in which great development is possible. Here, again,

as in the Indian building, will be seen the guiding hand of Mr. Alexander Howard.

The mineral resources of Burma will be shown by the Burma Corporation, the Burma Ruby Mines Co., and others.

A great effort is being made to make the Exhibition a starting point for the development of a properly organised trade in fancy articles of Burmese manufacture, such as lacquer, silk, ivory, silver, bronze, umbrellas, gongs, and toys. These articles are never made in factories, except to a small extent in the case of silk near Mandalay. A company is being formed by the Burmans themselves to undertake this duty in connexion with the Exhibition, to assist the Burmese villager, who depends upon his art practised at home, in extending the market for his wares. Government has recently appointed a Director of Cottage Industries, whose first duty is the organisation of the lacquer, silk and pottery workers; and it is also anticipated that the Government of Burma will initiate a system of credits to assist in financing these important industries.

May I end these brief remarks upon Burma by a quotation from a recent speech of His Excellency the Governor at Rangoon? Sir Harcourt Butler said:—

"I want people who come from all parts of the world and see the Burma Section standing in splendid isolation, with its national architecture and its sign of national life and industry, to carry away with them one fixed impression—that it is one of the greatest countries in the Empire, with great opportunities of prosperity before it, a country which has realised its opportunity and won its rightful place in the Exhibition."

I have now to crave your indulgence a few minutes longer while I briefly describe, with the help of pictures upon the screen, the buildings in which India and Burma's exhibits will be housed.

The first picture shows the Indian building as it will appear to a spectator in the N.W. corner. When William Morris was taken to the Exhibition of 1851 he murmured to himself, "It is all wonderfully ugly." I hope that none of those who come to the Exhibition next year will be prompted to say that of India or of Burma. This building, wich is being constructed by Sir Robert McAlpine & Sons, was designed by Sir Charles Allom: and I need say no more than this to assure you that the design and the decoration will be superlative, and the detail strictly correct. Every effort has been made to ensure accuracy and to avoid incongruity. I believe, and I have been at some pains to assure myself, that there will be no single detail in the building which is not actually based upon an Oriental original. The frontage of the building is some 140 yards, its depth about 130, and it stands in an area of 4½ acres. The ground will be carefully laid out and will contain one, or perhaps two, tea houses of a design in keeping with the main building, and a flagstaff, where the Indian flag will be flown on high-days and holidays.

The buildings are to stand on high ground and will overlook the vista of lakes which the lay-out plan of the Exhibition shows as lying between India at one end and New Zealand at the other. Behind them, but on lower ground and concealed from view, will be the new Exhibition Station of the Great Central Railway.

The first sod of our Indian building was turned by Lady Barnes on the 21st March, and we were the first Dominion to start building. We have got well ahead. The second Dominion building to be commenced was that of Burma, whose site is now covered by a multitude of workmen.

[Other pictures showed details of the frontage, a view of the Courtyard, 150 feet square, with ornamental water, 70ft. by 30 feet, in its centre, with the main entrance in face, surmounted by a dome 37 feet in diameter, and flanked by minarets 110 feet high, which His Majesty the King-Emperor graciously placed at the disposal of the Government of India.] After referring to 29 Kashmir panels, which will be utilised in the internal decoration, the lecturer proceeded:

We will now cross the grounds to the Burma Building. These alarming creatures, known as leogriffs, will not be at the spot shown, but will be in the grounds, guarding the main building. This building stands in two acres of ground and is the design of Mr. Adams Acton, of Sir Charles Allom's firm. The decorative part of the spires will be of Burmese teak, and will be carved in Burma and sent over to be placed in position. The building will be panelled inside with teak specially selected by the five big teak firms; and a large quantity of decorative work for outside the main building and for the bridge house is being made in Burma.

In conclusion, may I emphasise the hopes

that India bases on this meeting together of the citizens of the Empire? The watchword of this Exhibition is "Mutual understanding and better commercial knowledge." In the brief sketch which I have given you I have tried to show you how India hopes to improve her position by better commercial knowledge. A mutual understanding is, however, something which, at this particular stage of her progress, she values perhaps even more highly. She is on the threshold of her new venture, and she asks for nothing more than a "fair field and no favour." Both in her internal politics, and in her dealings with the other great integral parts of the Empire, she is faced with many difficulties, is embarrassed perhaps by many misunderstandings. If at the close of the Exhibition she has convinced the Empire—as I am sure she will—that she is still the same India whom so many of us have served and loved, and in whose whole-hearted service so many of Great Britain's best and bravest have laid down their lives, then, indeed, her purpose will have been accomplished; and she will go on from strength to strength with renewed confidence, and with enhanced pride in the feeling that she is one of the brightest jewels in the Empire's crown.

DISCUSSION.

The Chairman said they could have seldom listened to a more interesting paper. He wanted to emphasise one point. People had an idea that Wembley Park was a far-away place, and that because the Exhibition was to be held there, it would be a profound failure. As a matter of fact, it was quite close at hand. Wembley Park was chosen as the site of the Exhibition on account of its remarkable accessibility from all parts of the country. Close to the Exhibition were two main line stations—Wembley on the L. & N.W.R., and Wembley Hill on the L. & N.E.R., and a third station, with a capacity for 16,000 passengers hourly each way, had been constructed by the latter line in the middle of the Exhibition grounds in order to relieve Wembley Hill Station of a great deal of London traffic, and leave the railway free to deal with country visitors. Existing connections would permit of through trains being run to either Wembley or Wembley Hill Stations from all the main trunk lines in Great Britain, and the railway companies in every case had promised to develop these facilities to the utmost extent. So far as visitors from London were concerned, the situation of the Exhibition was ideal. Wembley was only six miles from the Marble Arch by road. Trains from Baker Street would take only ten minutes to reach the Exhibition on the Metropolitan Railway, and ten minutes from Marylebone by the L. & N.E.R. The Baker Street-Waterloo Tube ran into Wembley via Piccadilly Circus, while the District Railway could convey large numbers to Sudbury Station, whence frequent services of trams and omnibuses could be run to the Exhibition. There were 126 stations in the London area from which the Exhibition might be reached in an average time of 18 minutes, and from 120 city and suburban stations it was possible to travel there without changing. Trains to Wembley took from Baker Street, 10 minutes; from Piccadilly Circus, 15 minutes; from King's Cross, 16 minutes; from Charing Cross, 18 minutes; from Liverpool Street, 23 minutes; from Victoria, 24 minutes; from Finsbury Park, 24 minutes; from Clapham Junction, 21 minutes. Apart from the railways, Wembley was in tramway communication with Finchley and Hampstead, Paddington and Willesden, Hammersmith, Putney, Acton, and Ealing. The trams ran past the south entrance to the Exhibition. Omnibus services would run to all entrances along a number of new routes, and the new main roads, which had been constructed with the co-operation of the Ministry of Transport, would provide ample accommodation for the densest motor traffic. It was interesting to note that on the occasion of the Cup Final, the railways, buses, and trams carried about 235,000 people, the rush hours being from noon onwards. The match finished at, approximately, 5.30 p.m., and, despite the enormous crowd, all the Exhibition stations were cleared by 7 p.m. The Metropolitan Railway alone carried 152,000 people to and from Wembley Park Station, and at certain periods were delivering passengers at the rate of 1,000 per minute. He thought that when people knew these facts, they would form a different idea as to the accessibility of Wembley. The paper that had been read raised matters of immense interest. The statistics it contained showed that the growth of trade in India was very marked and progressive, and he thought that the author, in describing it as a new India, was quite correct, because the expansion in the directions indicated had been more marked in the last ten or fifteen years than for a very considerable period previous to that time. The Indian Tea Association were pretty sure to take care that they were properly represented, and he felt sure that, in the present prosperity of Indian tea, they would do it in no mean manner. He hoped that the audience would take the advice of Mr. Kendall and study the making of tea, because, no matter how good the quality, if it was not made properly it was like dirty water. In his concluding paragraph, the author appealed to all to make

the watchword of the Exhibition a mutual understanding and better commercial knowledge. In the present days of quick travel, we were in much closer touch with India than we used to be; people came from India to this country and went from this country in much larger numbers than formerly, and in that way we were getting to know and understand each other very much better. He trusted that the Exhibition, which would cause a large influx of Indian people, would be a further means of promoting that mutual understanding.

Lieut.-General Sir Travers Clarke, K.C.B., K.C.M.G., said that though he had served in India and Burma some years he did not propose to talk about those great countries, but as the author had been good enough to associate him with two things—transport and diseases, he would say a few words on these two important matters. Just before he came to the meeting, a gentleman connected with the Press said to him: "I suppose you never want to hear the words 'Cup Final' again?" He asked why, and the reply was: "They say that you were brought on the Empire Exhibition staff because you knew a good deal about moving people and troops, and if it had not been for your gingering up the railway companies and bus companies and char-à-banc people, you would not have had a crowd at Wembley you could not put in when you got them there." When the Exhibition was opened, people would find they could get to Wembley and get in very much faster than they expected. As regards the second point, the bacillus, he believed there was going to be a very interesting section on tropical diseases—but he was not responsible for tropical diseases, indeed he had requested that the section be renamed "Tropical Health." He wished to pay a tribute to the author for his inspiring paper. He believed people would go to Wembley if only to see the Indian and Burma pavilions. In his judgment, the Exhibition was planned to be, in the first place, a great family party of the Empire. The nations of the British race and British blood which had been set up in every continent of the world, and those other countries under the British flag which were now learning the lessons of self-government and orderly civilisation under the tutelage of the Empire would come together at Wembley, bringing with them proofs of their industry, to meet and talk over the future in the light of the experience of the past. Secondly, the Exhibition was planned for the fostering and advancement of British Empire trade and industry, to help to repair the ravages and losses of the Great War. Then, in this attempt to promote economic unity within the Empire, people who went to the Exhibition and passed through all the wonderful pavilions erected by the home countr the Dominions and the Colonies, would see the directions in which trade and industry could best be fostered. That led up to the next stage, and possibly the most important stage for those gentlemen who held high positions in the Home, Dominion and Colonial Governments, and that was Empire Development. The statesman who made the remark, quoted in the paper, that Empire development depended, to a certain extent, on three M's—Men, Money and Markets—he thought, was quite right; but he left out what were really the three main things, which might well be called the three V's —Vigour, Virility and Vision. The Empire was not short of vigour; the Great War had shown that. The Empire was not short of virility; the great Dominions proved that. But, as regards Empire development, have we got the vision? Whatever view was taken of Empire development, it could not be a parochial one. They who were specially connected with the British Empire Exhibition thought that if those who were in high positions in the Home Government, the Dominions Governments and the Colonial Governments, would go to Wembley and study the question, they would see how best to focus the great problem of Empire Development.

Mr. T. McMorran, of Messrs. Walter Duncan & Co., East India merchants, said he agreed with the reader of the paper that the Exhibition would bring us into closer touch with India, and he hoped that the Royal Society of Arts and its fellows would use their influence to bring their friends to the Exhibition, in order that they might be able to take a greater and more intelligent interest in things Indian. It would be nothing short of a tragedy for India if, at the end of an Exhibition which would bring people into touch with her handicrafts and the products she can offer this country in exchange, there was no individual here to whom those who wished to do trade with India could go for further information. He thought it most desirable that there should be a definite officer set apart for dealing with inquiries of the kind. For that reason he would venture to say to those who had a voice in such matters, that they should think twice before they abolished the office of the Trade Commissioner for India. Referring to the lecturer's remarks about the progress of India since the Great Exhibition, he had looked up the consumption of tea in this country in 1851, and he found it was about 60 million pounds, India's contribution being less than one per cent. To-day the quantity of tea consumed in the British Isles was over 400 million pounds, and India's contribution almost 70 per cent. China, which at that remote period was providing practically the whole of the tea consumed, was now supplying only one per cent. What was needed was to bring Indian commodities to the notice of the people of this country, who would appreciate

them, if only they knew where they could be obtained.

Lieut.-Colonel Sir A. Henry McMahon, G.C.M.G., G.C.V.O., K.C.I.E., C.S.I., in proposing a vote of thanks to the reader of the paper and to the Chairman, said his double task was a pleasant and easy one. They were very much indebted to the reader of the paper, who had shown that he had a complete mastery of the subject with which he dealt, and as that subject was the Indian Section of the British Empire Exhibition, it increased the hopes they had previously derived as to the way in which India would be represented at that great Exhibition. It was most pleasing to all of them to know that India was going to take a leading part in the Exhibition, and especially to those who were connected with the management of the Exhibition. Four of the five members of the Board were present. One of them, the Chairman (Sir Charles Campbell McLeod) was amongst the leaders of the commerce and industry which had made India what it was to-day, and enabled it to take the part it was taking in the Exhibition. The Royal Society of Arts was proverbially quick at "spotting" a good thing, and that was why it was taking so much interest in the British Empire Exhibition. The paper just read was the second that had been given under the Society's auspices in connexion with the Exhibition, and the aid it was affording was highly appreciated. This work was no new thing for the Society. To it was due the credit of having laid the foundations of the Great Exhibition of 1851, and of having supported its then President, the Prince Consort, in making it the great success it was.

Sir Charles H. Armstrong (Chairman of the Great Indian Peninsula Railway Company), in seconding the vote of thanks, said the author of the interesting and instructive paper to which they had listened had told them that India would have an exhibit of arts and craftsmanship and also of carpet-weaving and a few other things; but no particulars seemed to have reached him about the exhibits, and so he was unable to give any special details. On the other hand, he had stated that Burma had organised a very effective exhibition of what might be called the smaller articles. He (the speaker) hoped that India was not going to lag behind in this respect, because there was a very great opening for trade in the miscellaneous articles that came from India. All the main articles mentioned in the paper, such as tea and timber, were, of course, well-known, and the trade in these could very well be handled by Indian merchants in London, but there were heaps of other things, in a small way perhaps, in which there would be a large trade if properly organised. In India itself, so far as he knew, these trades were not properly organised, and he hoped that if the High Commissioner and others, who were taking an interest in this matter, found that at the Exhibition the particular articles to which he was alluding attracted special attention, they would draw the attention of the Government of India to the fact, and endeavour to put some of those trades on a recognised, businesslike basis. The author had stated that India was not to have a cinema at the Exhibition. As regards the Great Indian Peninsula Railway, they were preparing a special film, which would be exhibited in order to show places of interest on the line. He hoped that the railway would, at the same time, distribute small leaflets giving particulars of some of those places, and also indicating the cost of a short visit to any or all of them. He was particularly hoping that Americans would be greatly encouraged to go to India and see the many interesting places there. He was in India three or four months ago, and the Americans were coming then. He thought that between four and five thousand went to India last year, and they wanted, if they could, to double or treble that number.

The resolution was carried unanimously, and the meeting terminated.

OBITUARY.

Thomas Jenkinson.—Mr. Thomas Jenkinson, well known in connexion with the sugar refining industry, died on July 19th at his residence, No. 1, Warminster Road, South Norwood Park, in his seventy-sixth year. He was formerly in sole charge of the Liver Sugar Company, a small concern in Liverpool long since extinct, combining the duties of manager, secretary and chemist. In 1878 he came to London with Mr., afterwards Sir, Henry Tate, Bt., to take control of the Mincing Lane Saleroom of Messrs. Henry Tate & Sons, who had opened their large sugar refinery at Silvertown, E. When, on the outbreak of the Great War, the Government took steps to secure adequate supplies of sugar in view of the cessation of the usual importations from the Continent, and authorised Messrs. Tate to buy large quantities, it fell to the lot of Mr. Jenkinson to purchase, during August, 1914, approximately a million tons from various sources. The Royal Commission on Sugar Supplies came into existence a little later, and assumed responsibility for the sugar industry in all its branches, this arrangement continuing until the Commission was dissolved in 1921. Mr. Jenkinson retired from the firm of Messrs. Tate in 1916, with the respect of all with whom he came into contact throughout his long career in Mincing Lane. He was a Fellow of the Royal Society of Arts, having been elected as far back as 1893.

GENERAL NOTES.

Penny Postage.—Writing to the *Times* (28th July), Lord Blyth remarks that the British public must have been astonished to read the Postmaster-General's statement in presenting the Post Office Estimates to the House of Commons, with its implied suggestion of a cold-shoulder to any further reduction of the three-halfpenny letter postage to a penny. If, in the reconstruction of the world, we are to derive the utmost advantage from our advantageous position, we must, Lord Blyth urges, have the most up-to-date facilities for cheap and easy postal communication. "When presiding recently at a meeting of the Dominions section of the Royal Society of Arts, the Duke of Devonshire drew attention to the manifold products that are special features of different areas of the British Empire, and emphasised the vast fields for exchange of commodities and commercial development that await British enterprise. There can be no doubt that with the Prince of Wales's Presidency of the British Empire Exhibition and his striking message to our kinsfolk everywhere, the great Exhibition of 1924 must be a memorable achievement in augmenting trade and industry and in consolidating the Empire. Its useful object lessons would be multiplied manifold if meanwhile a cheaper Imperial postage were in operation."

Fuel Research Board.—The Lord President of the Council has accepted with much regret, the resignation of Sir George Beilby, LL.D., F.R.S., after nearly seven years' voluntary service as Director of Fuel Research and Chairman of the Fuel Research Board under the Department of Scientific and Industrial Research. The Board was established in 1917 to investigate the nature, preparation and utilisation of fuel of all kinds. The Lord President has appointed Mr. C. H. Mander, D.Sc., M.I.Mech.E., A.M.Inst.C.E., to be Director of Fuel Research, and Sir Richard Threlfall, K.B.E., F.R.S., a present member of the Board, to be Chairman. The Hon. Sir Charles Parsons, K.C.B., F.R.S., will continue his membership of the Board for a further period. Sir George Beilby retains his membership of the Advisory Council of the Department, and has consented to act as Honorary Adviser to the Board. The following gentlemen have accepted appointment as additional members of the Board:—Mr. R. A. Burrows, Sir John Cadman, K.C.M.G., D.Sc.; Dr. Charles Carpenter, O.B.E., D.Sc.; Mr. Samuel Tagg; Prof. Sir James Walker, D.Sc., LL.D., F.R.S.; Prof. R. V. Wheeler, D.Sc.

British Association.—The ninety-first annual meeting of the British Association for the Advancement of Science will be held at Liverpool from September 12th to 19th, 1923. The President, Professor Sir Ernest Rutherford, F.R.S., will deal in the inaugural address with "The Electrical Structure of Matter." The following sectional addresses will be delivered:—The Origin of Spectra, by Prof. J. C. McLennan, F.R.S.; The Physical Chemistry of Interfaces, by Prof. F. G. Donnan, C.B.E., F.R.S.; Some Aspects of Evolutional Palæontology, by Dr. Gertrude Elles; Modern Zoology: Its Boundaries and Some of its Bearings on Human Welfare, by Prof. J. H. Ashworth, F.R.S.; The Position and Opportunity of the British Empire, by Dr. Vaughan Cornish; Unemployment and Population, by Sir W. H. Beveridge, K.C.B.; Transport and its indebtedness to Science, by Sir H. Fowler, K.B.E.; Egypt as a field for Anthropological Research, by Prof. P. E. Newberry; Symbiosis in Animals and Plants, by Prof. G. H. F. Nuttall, F.R.S.; The Mental Differences between Individuals, by C. Burt; The Present Position of Botany, by A. G. Tansley, F.R.S.; The Education of Demos, by Prof. T. P. Nunn; Science and the Agricultural Crisis, by Dr. C. Crowther. An evening lecture on The Study of Man, will be given by Prof. G. Elliott Smith, F.R.S.

Stock Feeding.—Writing in the *Journal* of the Ministry of Agriculture, Mr. E. T. Halman discusses the use of mineral substances in stock-feeding, and points out that an ordinary mixed diet contains all food items essential to health, with the exception of sodium chloride, for which rock salt is generally supplied. In the case of pigs, which are largely fed on grains and grain by-products, the rations are apt to be deficient in calcium, which is necessary for the production of bone. To correct this Mr. Halman recommends that in the diet of pigs, clover, lucerne or vetches should be included, or some mineral lime-containing substance, such as steamed bone flour. There is also a heavy demand for mineral substances in the case of all young growing stock, and dairy cows in milk. A suitable mineral mixture should, therefore, be supplied in these cases, and the usual and cheap sources are small coal, chalk, rock salt, and steamed bone flour, these being placed in the troughs in the feeding yard so as always to be available when the animal feels that it wants them.

Rose Oil Production in Bulgaria.—According to a report received from H.M. Legation at Sofia, since 1915 the culture of roses in Bulgaria has considerably declined for various reasons, principally on account of the absence of labour during the war and the higher prices which could be obtained by growing cereals. The average annual production before the war was 4,000 kgs., and the principal consumers were France, Germany, England and the United States. The production of rose oil during 1922 amounted to about 2,000 kgs. Compared with the previous year's production this represents an increase of 500 kgs. The price varies between 16,000-18,000 leva per kilo, but not much business has been done. (The present exchange value of the leva is about 630 to the £.)

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FRIDAY, AUGUST 10, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

PROCEEDINGS OF THE SOCIETY.

SIR GEORGE BIRDWOOD MEMORIAL LECTURE.

FRIDAY, JUNE 15TH, 1923.

THE MOST HONOURABLE THE MARQUESS CURZON OF KEDLESTON, K.G., G.C.S.I., G.C.I.E., P.C., F.R.S. (Secretary of State for Foreign Affairs), in the Chair.

THE CHAIRMAN said he was informed that the present was the seventh time he had had the honour of presiding at a meeting of the Society dealing with Indian affairs, and the fact that those seven occasions had been spread over twenty to thirty years would indicate that his interest in India and in Indian subjects had been continuous. The lecture to be delivered was one of a series given annually in memory of Sir George Birdwood. Those who were regular attendants at the meetings of the Society would recall the many occasions upon which, after learned papers had been read, speeches infinitely more learned were made by that distinguished man. He did not think that in the whole course of his (Lord Curzon's) experience of public men he ever met a man who, in his way, had either a more remarkable brain or a more remarkable memory than the late Sir George Birdwood. There was scarcely any subject of Indian art, Indian history, Indian customs, Indian archæology and Indian folk-lore with which he was not familiar; and whenever he heard Sir George discourse on those matters he always recalled the familiar lines of Goldsmith :—

"And still they gazed and still the wonder grew,
That one small head could carry all he knew."

The only point in which that description did not apply to Sir George Birdwood was that his head was exceptionally large. He believed that three, if not four, lectures had been delivered in memory of that eminent man; and he was all the more pleased to be present that afternoon because, in addition to paying a tribute to Sir George's memory, he had the pleasure of introducing one of his old friends and colleagues in India, Sir John Marshall. It was just about twenty-one years ago that he succeeded in getting Sir John Marshall to go to India. No man ever did a better thing for India than he did on that occasion. When he went to that glorious country he found its priceless and beautiful monuments in a state, he would not say of decay, although in many cases that was true, but at any rate of comparative neglect; and he felt that it was necessary to apply to their conservation, and, where necessary, repair, a first-rate and trained intelligence. It was then that he was fortunate enough to have recommended to him Sir John, then Mr. Marshall, who had already done remarkable work in excavation in Europe. Sir John went to India as Director-General of the Archæological Department, and he brought to that work the knowledge and skill of the trained expert, and the personal zeal of the enthusiast. During the twenty-one years of his residence in India—because he had practically devoted his life to the work—he had elevated the science and art of Indian archæology to a new level. He had been responsible not merely for the excavation of many wonderful places hitherto unknown or lost to view, but had been instrumental in bringing the general conditions of the Indian monuments of every period—the Buddhist, the Brahmanical, and the Moslem—to a state of perfection which rendered them the best preserved series of monuments in the world. He had at the same time, with his skilful pen, brought out year by year a series of reports which were a model of what such productions should be. In the course of a holiday in England Sir John was going to give the audience the benefit of his observations on one branch of his studies. He would not anticipate anything that Sir John might say, but in his opinion the Society was fortunate in having an address from him, because he was one of those men who had done most, among all the men he knew, in the carrying out of a great duty in India—he looked upon the preservation of ancient monuments as a national duty—and who by so doing had exercised a great, a growing and a beneficent effect upon the relations between the two great peoples, the British and Indian, whose destinies were interlocked in that country.

The lecture delivered was :

INFLUENCE OF RACE ON EARLY INDIAN ART.

By SIR JOHN MARSHALL, C.I.E., M.A., Litt.D., F.S.A.,

Director-General of Archæology in India.

Any one privileged to deliver a lecture in commemoration of Sir George Birdwood must be conscious, as I am, of one great

advantage. He can choose almost any subject he likes from the realm of those relating to India, and he can be sure that the subject chosen is one in which Sir George Birdwood would himself have been deeply interested; in other words, he can be sure that it will be quite appropriate to the occasion. Whether one turns to the history or to the religions of India, to her folk-lore or her ethnology, to her arts and crafts, or to her industries, or her agriculture, it is the same. To each and every one of these subjects, and to many more besides, Birdwood's genius and imagination contributed something of real and permanent value, for which each of us, in his own sphere, is devoutly grateful. Speaking from this place last year Sir Thomas Arnold asked your indulgence for what he described as the pedantic character of his lecture—pedantic, as he alleged, in comparison with the weighty and comprehensive problems handled by his predecessors. I am afraid that I, too, must claim from you the same indulgence. Curiously enough, although I was not aware of it at the time I selected my subject, I find that it is in a measure complementary to Sir Thomas Arnold's. Sir Thomas, you will remember, dealt with Indian painting in its relation to Moslem culture. This afternoon, I propose to say something of Indian Art in the pre-Moslem period, and I shall endeavour, in particular, to analyse the factors which contributed mainly to its genesis and subsequent evolution. The subject, I need hardly say, is a big one, and the most I can do, in the limited time at my disposal, is to sketch in the bare outlines and leave it for another occasion to amplify and fill in the details.

And, in the first place, I want, very briefly, to remind you of the most salient features of this Indian art of the pre-Moslem period. The history of this art divides itself conveniently into three distinct chapters. First, there is the Early Indian School, covering some five centuries—from the third century B.C. to the second century A.D.—and extending over most of India except the Punjab. When this school first appears on our horizon in the sculptures of Bharhut, and Bodh-Gaya and Sanchi, the feature that characterises it most is its keen appreciation of decorative beauty. From start to finish this decorative quality, this sense for rhythmic flowing ornament, and particularly for floral ornament, is the special prerogative of the Indian artist. It is his birthright. You will find it inherent in every phase and in every period of Indian art, whether it be in these early sculptures of the Buddhists, in the mediæval paintings of Ajanta, in the elaborate architecture of the Hindus and Jains, or in the fairy-like structures of the Mughals. And, seeing to what a high pitch this sense for the decorative had been developed in the earliest monuments that have survived to us, we can hardly doubt that it had come down from an immemorial antiquity. But, side by side with their rich decorative beauty, there is another feature that strikes us forcibly in these efforts of the Early School. It is, that the modelling of the human figure is still quite crude and primitive. Consider, for example, the well-known statue from Parkham, near Muttra. When it was carved, Indian art was in much the same stage of progress as Greek art had been in the sixth or seventh century B.C. It was not yet freed from the law of "frontality" or from the trammels imposed by the "memory image" of primitive man. Or consider the reliefs on the Stupa of Bharhut, which are no more rudimentary than other contemporary sculpture. They are portrayed merely as silhouettes sharply detached from their backgrounds, the only attempt at modelling being made by grading the several planes of the relief in distinctive layers and then rounding off their contours. In these figures of Bharhut the interest of the artist in the human form, as an object worthy of portrayal, had scarcely begun to dawn. The task before him was merely to narrate the story of the Buddha—that story in which all living things were co-equal—in the simplest and most unaffected language that his chisel could command, much as any romance ballad writer might have narrated it. Of expressing emotion or idealising form he knew nothing, nor did he make any pretence at either. Man to him was as yet merely an incident in the scheme of creation—not, as he became later, the lord of it. Little by little the early school surmounted many difficulties of technique, and by the beginning of the Christian era it was able to portray the human form with considerable skill. But it was not until the Golden Age of India—that brilliant age between the fourth and seventh century of our era—that art made any real effort to interpret the beauty of the body or the aspirations of the soul.

Now for the second chapter of our Indian

art. This second chapter is concerned with the Græco-Indian School of the North-West, which was established by the Bactrian-Greek invaders in the second century before Christ and kept alive by their successors—the Scythians and the Parthians and the Kushans--until the fifth century of our era. This school starts by being essentially Greek. This relief, for example, on the screen, is one of its products—a bust of Dionysus in silver *repoussé* from Taxila, holding the two-handled wine cup in his hands; and the next, which belongs to a little later date, is a statuette in bronze from the same site—a figure of the Egyptian Harpocrates—the Child God of Silence. But, though Greek at the outset, the school gradually absorbs many heterogeneous elements from Persia and Scythia and India, and eventually becomes thoroughly hybrid in character, in which phase it is known commonly as the "Gandhara School"—from the district of Gandhara (that is, roughly, the North-West Frontier Province) where it mainly flourished, or as the "Græco-Buddhist" School, from the fact that it came to be devoted almost exclusively to the service of Buddhism. The few typical examples of its sculptures that I shall put before you will suffice to show the character of its art and also to illustrate the steady process of Indianisation that it underwent up to the close of the fifth century A.D. The features of this school that specially deserve notice are, first, that in spite of this art being exotic on Indian soil, it exhibited nevertheless a remarkable vitality in the North-West, and its influence managed to survive there for at least six hundred years. Secondly, it had the merit of inventing the chief types of the Buddha which afterwards became stereotyped in Buddhist art; and besides supplying India with many *motifs* and ideas, it performed a specially valuable service in teaching the Indian artists of the National School how to solve many of their problems and difficulties. In these ways this quasi-classical art of the North-West undoubtedly did much to promote the growth and development of Early Indian Art; but, on the other hand, there is no evidence to indicate that it exercised any profound influence on the esoteric character of that art.

And now for the third and most important chapter, namely, the Gupta School of the mediæval age, which sprang into being under the Imperial Gupta Empire in the fourth century and reached its fullest maturity in the seventh. This Gupta School is essentially Indian—the lineal descendant of the Early School—but the horizon of art has been vastly widened in the meantime. It retains all the decorative beauty of the Early School, and in many ways improves upon it; but it raises art on to an altogether higher plane. The Gupta period, as you know, was the Golden Age of India, the greatest of her creative epochs, when there was an outburst of mental activity such as Greece had experienced some eight centuries earlier, and such as Italy was to experience a thousand years later. The results of this activity were made apparent in every direction. In the political sphere they resulted in resuscitating the Imperial idea which had been dormant since the days of the Mauryas, and led to the foundation of the great Gupta Empire. In the field of religion they found expression in the revival of Brahmanism, and along with Brahmanism in the revival of Sanskrit, which was the sacred language of the Brahmans. It was during this period that Kalidasa wrote his immortal plays; that the Puranas were compiled; that the laws of Manu took their present form and that mathematics and astronomy reached their highest perfection. And this new intellectualism affected art as much as anything else. It brought it under the control of reason. Henceforth there is a clearer apprehension and more lucid definition of form; proportion and balance become more logical; rhythm and composition more thoughtful; and—what is most important of all—the human form now becomes the main objective of the artist, not for the sake only of its inherent beauty, but for the sake of the deeper mental and spiritual qualities that are latent in it. In the whole history of Indian Art there is no feature more interesting than the humanism, if I may be permitted to use that term in a somewhat narrower sense than is usual—the humanism which took possession of it in this Golden Age, but which vanished again at its close. The effect on Asia of this Gupta School was immense. It was the fountain-head of that broad and wonderful stream of Buddhist and Hindu art which flowed over the length and breadth of India, and from India over the whole of the Middle and Far East, bearing along with it the highest traditions and the noblest ideals of the Indian people.

Now, the two questions which I want

to try to answer this afternoon, are these: "Whence came the national decorative and illustrative art of India?" And, secondly, "To what are we to attribute the sudden outburst of intellectualism and humanism in the Gupta epoch?"

Among most writers on Indian Art it has been the fashion to give to the Indo-Aryans—that is, to the Nordic people, who brought with them the Vedic civilisation into India—the credit for all that was best in ancient Indian culture; and in this "best" they have naturally included the fine arts. Let us, however, look at the facts. If it was these Vedic people who were the authors of early Indian art, we should expect that art to be strongest in the districts where the Vedic peoples established themselves: that is, in the North-West Frontier and the Punjab; and weakest in the districts most remote from their influence. But what we actually find is the very reverse. The Nordic peoples entered India from the north-west, and expelled or exterminated the bulk of the Dravidian and other pre-Aryan population from the "land of the five rivers." But the further they progressed, the fewer grew their numbers. Hence, in Hindustan and Central India, instead of sweeping away the older inhabitants in front of them, they gradually coalesced with them, forming a mixed stock, and evolving a hybrid Aryo-Dravidian culture. Still further to the south, and in districts more remote from the Punjab, the pre-Aryan races remained practically intact. Now, the decorative art of which I have spoken has always flourished most strongly in the South of the Peninsula, or in the districts furthest from the Punjab. It is found in a weaker and more modified form in Central India and Hindustan, and it is weakest of all in the Punjab. Broadly speaking, all the Indian art of to-day is pervaded by a wonderfully decorative charm, but it is as one goes southward that this charm becomes more apparent, and it is in the Madras Presidency and Ceylon that it reaches its fullest and most spontaneous expression. Nothing, to my mind, in the whole domain of Indian art, is more fascinating than to watch a south-Indian artist—it may be a mere child—evolving and tracing out some rich and highly complex pattern; nothing more amazing than his dexterity of touch, the fertility of his imagination, and his unerring instinct for rhythm of line. And what is true of Indian art to-day, was equally true in the early centuries of the Christian era. It is in the south of India, in the sculptures of Amaravati, that we find the richest, most rhythmical, and most imaginative designs. In the Punjab, as my excavations at Taxila have abundantly proved, there was little or no art of any kind before the arrival of the Greeks; and it was, I suspect, because the Punjab was so destitute of indigenous art, that it offered such a fertile soil for the propagation of this foreign school. It is clear, therefore, that it was not to the Indo-Aryans, but to the earlier Dravidian or other pre-Aryan people, that India was indebted for her natural and inborn love of ornamental design. All that we know of the Indo-Aryan or Vedic people suggests that in the domain of the formative arts they possessed little natural ability. Their genius lay in other directions. They were men of great bodily and mental vigour, but their mentality was of a practical, not of an æsthetic order. Their interest focussed mainly on the necessities of life, on man (that is, on Indo-Aryan man), and on his welfare. Their natural disposition was towards law and order; they had a strong moral sense of right and wrong; keen powers of observation; and an exceptional faculty for conscious, logical thought, as compared with the sub-conscious emotionalism of the pre-Aryan races. These gifts and qualities of the Indo-Aryans sufficiently account for their superiority over the races with whom they came into contact, and are reflected in the highly organised system of Vedic society; in the lucid practical structure of the Vedic language; and in the anthropomorphic character of their religion. But, though the Indo-Aryan people had little natural ability for the fine arts, they made, nevertheless, a very important contribution towards their development and towards the development of culture, generally, in India. We have already seen what effect their immigration had on the art of the North and of the South of India. Let us consider what happened in the midland country of Hindustan and Central India. In this midland country, *Madhyadeśa*, as it was called in ancient days, the Indo-Aryans inter-married with the older population, and gave birth to a new racial type—a hybrid, known as the Aryo-Dravidian or Hindustani type. The fusion of the two races which took place in this area had the happiest result for India, just as the fusion of the Nordic and Mediterranean

stocks had the happiest result for classic Greece. The Aryo-Dravidian peoples whom it produced combined in themselves the sensitive emotional qualities, the intuitive genius, and the unconscious artistry of the older inhabitants with the more practical nature and the philosophic mentality, as well as the humanism, of the Indo-Aryan race. Henceforth, the midland country becomes the centre of culture and thought, as it also becomes the centre of political power, in India. Among the older, pre-Aryan people of India, as among the peoples of the Far East, man had been merely an item in the landscape—no higher than the creatures or living things around him. Among the Indo-Aryans, as among the Nordic peoples generally, man came first and foremost in the order of creation; and from man radiated—to man were subordinated—all other interests. So long as the Indo-Aryans preserved their blood intact, this intense "humanism"—this egoism of the species—found expression in their thoughts, in their literature, and in their religion. It could not find expression in formative art, for the simple reason that the Indo-Aryans were destitute of natural artistry; they did not know how to articulate their ideas with the chisel or the brush. But once their race had been blended with the Dravidian, the mixed stock which resulted from the union found itself possessed of the means of putting its thoughts into visible concrete form. In the sculptures of Bharhut we see the awakening of this new power, we hear the first lisping accents of humanism and intellectualism. In the sculptures of Bodh-Gaya and Sanchi the voice is slowly gaining strength, and then, after an interval of silence—which, unfortunately, is almost a blank in the history of Indian art—it is heard in the paintings of Ajanta and in a multitude of contemporary sculptures, in all its force and richness. Unfortunately, as time passed, the blood of the Aryans grew thinner, and the invigorating stimulus that they had exercised on Indian art gradually waned. By the tenth century the controlling mentality of the Indo-Aryans is already fading away; humanism has all but vanished, and lucid definition and restraint are giving place once more to the rich but unrestrained ornament in which the Dravidian fancy has always delighted.

The part played by the Indo-Aryans in India finds a close parallel in the part played by the Nordic peoples in other countries, but to-day I must content myself with citing only the parallel case of early Greece. I am not, of course, so rash as to assume that the Indo-Aryans who invaded India were necessarily of the same race as the Achæans who established themselves in Greece. Community of language does not prove community of race; but kinship in speech does at least suggest kinship in other directions also, and it is legitimate to believe—though there are not sufficient data to prove whether we are right or wrong—that the Indo-Aryans may originally have sprung from the same stock as the Nordic invaders of Greece. In any case the parallel between the two countries is too striking not to be significant. Like the Dravidians of India, the people whom the Aryans found established in the Balkan peninsula, in the islands of the Levant, and round the coast of Asia Minor were gifted with a remarkable natural genius for decorative art. To appreciate the beauty of this art, one has only to recall to mind the richly carved goblets, the engraved gems, and the painted vases of early Ægean manufacture. But, exquisite as much of this Minoan and Mycenæan art was, it had nothing of the intellectual or humanistic qualities, which distinguish the later classical art of Greece. In Greece, as in India, it was only in the districts where the older population survived and amalgamated with the Nordic invaders—in Attica, that is to say, and the Peloponnese in the islands of the Ægean and on the coasts of Asia Minor—that Greek art was reborn again in its new and classic beauty—as Indian art was reborn under the Midland Empire of the Guptas. And in Greece no less than in India it was the northerners who imparted to art its rare power of definition, its splendid humanism, and its intellectual beauty. In India, in proportion to the size of the country, the ferment supplied by the invaders from the north took longer to react than it did in Greece; and it goes without saying that there were wide differences between India and Greece in art no less than in thought.

In classical Greece the keynote of culture was intellectualism. In some of his admirable chapters on classical Greek art Mr. March Phillipps has well expressed the meaning of this intellectualism. It was the faculty for keen observation, for lucid reasoning, for hard logic and for clear definition. And

in the golden age of Greece this intellectual faculty was strictly limited to the measure of the human mind; it focussed itself on man and on all that appertained to man. It made man the measure of all things—even of the Gods themselves. There is nothing which gives us a clearer perception of the essentially humane and intellectual outlook of the Greeks than their notions of divinity. The Greek Gods are mortal, because no thought was ever conceived of them which transcended human expression. There is no mystery, no vagueness, nothing supernatural or emotional in the graven deities of Greece, for the reason that such ideas formed no part of the mental equipment of the Greek. Their definition is a mortal definition —man idealised, it may be, but nothing more.

In India, intellectuality and humanism never went so far as they did in Greece. Indian architecture of the classical period is dominated by the same logical qualities as Greek architecture. It exhibits the same structural propriety and the same love of symmetry and proportion, the same appreciation of plain surfaces, the same restraint of ornament—though ornament, I should add, is richer and more varied in India than it is in Greece. On the other hand, the form in Indian architecture is not so pure, the refinement of line not so great, nor the definition of detail so clear as in the Greek. In other words, the sense for the decorative was greater in India, but it was less under the control of conscious thought. In sculpture and painting, again, the Indian artist found his highest inspiration in the human figure. The world in which he most delighted was the world of men and women. In the Ajanta caves he painted his models in a thousand different attitudes, studying them from the life, and revelling in the beauty of their figures, in the loveliness of their features, in the multiplicity of their poses, in the vital flowing lines of their forms. But over all this human and intellectual art, he cast the charm of his decorative fancy, which he had inherited from his Dravidian forbears; and behind all this humanism there lay a spiritual background of which the Greeks knew nothing. This spirituality is inherent in the soil of India; it is rooted in the soul of her people; but in the formative arts it found its true voice only during the brief and spacious age of the Guptas, when the impulses of thought and art were accentuated to their highest degree, and when closer contact had been established between the two. It is in the sculptures and paintings of Buddhism that this spirituality reaches its highest expression. At its outset Buddhism appealed, by its sheer ethical logic, to the philosophic mentality of Aryanised India; but by degrees, as the Aryan element weakened, it became less rationalistic, more and more spiritual; and it ended by being reabsorbed into the essentially emotional Hinduism of the later Middle Ages. In the Gupta epoch, the spiritual had not yet mastered the intellectual, but Buddhism was no longer satisfied with the old ideals; it was conscious of needs which philosophy could not meet, of yearnings which intellect could never satisfy; and it sought to express these deeper, inward aspirations through the medium of its painting and sculpture. Unfortunately, in their hieratic art the Buddhists had to observe the strict conventions imposed by the conservatism of their faith; and they were hedged in and trammelled especially by the rigid canons of the Gandhara School, where Buddhist iconism had its birth. But, in spite of these conventions the Buddhist artists managed nevertheless to infuse into their sacred images such definition of form as their intellectuality required, and such spiritual character as was capable of expression. The spirituality of these figures is not the spirituality of Christian art, not the spiritual emotion that we see, for example, embodied, in the figures of Michael Angelo, the haunting wistfulness, the vague and anxious perturbation of soul, the restless longing for the Infinite, which seems never capable of fulfilment. It is the spirituality of Buddhism, which seeks to glorify the mind and spirit in one. The spirit which these figures of the Buddha and the Bodhisattvas breathe, is the spirit of divine compassion and divine peace—not the human tranquillity, the self-sufficient majesty of Greek Art, but the peace of heart and intellect which come from the contemplation of the Infinite. We must be careful, however, not to overestimate, not to lay too much stress on the spiritual side of this art. Spirituality is always there, always somewhere beneath the surface, but the artists of Ajanta did not look at life from beneath a cowl. They saw life clearly and they saw it whole. They gloried in the beauty of humanity, they gloried in the world around them, and they gloried in their own power to interpret what they saw and what they felt.

Though I have dwelt particularly on the effect of race and racial fusion on the culture and art of classic India, we must not forget that there were other subsidiary factors besides race which contributed towards their evolution. Geography and climate both played their parts, and a greater one still was played by religion, though not so great perhaps in the case of Indian as in the case of Moslem art. Then, there is the influence of other nations and foreign invaders which must be taken into account—of the Persians, for example, and of the Greeks and of the Scythians. The debt which Indian Art owes to all these peoples, and most of all to the Persians and Greeks, is a big one. But making full allowance for all these factors, and putting everything possible to their credit, it yet remains true that they fail to explain the phenomenal development of thought and literature and art in the Gupta epoch. The chief and primary cause of that development is a racial one: the mentality of the Aryo-Dravidian people. Among the paintings of Ajanta is one of a dark Dravidian girl in the arms of her fair Aryan lover. I think you will agree with me that this picture is curiously emblematic of the fusion of races that produced this art.

DISCUSSION.

The Chairman (Lord Curzon of Kedleston), in moving that a hearty vote of thanks be accorded to the lecturer, said he was sure everyone present would agree that they had seldom heard a more scholarly lecture, because it was obvious that the reflections to which they had listened were those of a man who had profoundly studied his subject, and who also was gifted with natural imagination and culture. Accordingly he had not merely presented the familiar exhibition of scenes which they might or might not have witnessed before, but a correlation and explanation had been given of them with the thought and the art of different periods, which could only have emanated from a man who had devoted an instinctive mental power to the examination of his theme. Sir John Marshall was to be congratulated on having chosen the subject on which he had lectured. When speaking about Indian architecture, he thought the majority of English men and women were much more inclined to think of the Moslem architecture of India than they were of the Indian, the reason being not merely that the buildings were, in many respects, more beautiful, but that they made a more natural appeal to the Western intelligence. Consequently, when visitors went from this country to India it was found that they flew instinctively to the glorious buildings of Agra, Delhi, and Lahore, where they saw perhaps the most delicate and exquisite fabrics ever raised by man, employing the most perfect and beautiful of materials, and combining with all the skill of the native artist a good deal of influence imported from the West. It must be remembered, however, that those most beautiful buildings were relatively modern. He was not, of course, speaking of the great monuments of Moslem architecture belonging to the Afghan and other periods in different parts of India; he was alluding to the monuments of the Mogul period alone. There were some who were apt to forget that when Shah Jehan was finishing his tomb, the memorial to his wife, Charles the First was on the throne in this country, and the tomb was not finished, as far as he remembered, before that monarch had gone to the scaffold. It was with a much earlier period and an entirely different art that Sir John Marshall had been dealing in his lecture. There, again, he thought there was often a popular misconception. Those who had travelled cursorily in India were perhaps apt to think, from specimens of Hindu architecture, that they had seen in popular places, that it was an architecture which was base, grotesque, clumsy, sometimes bestial, and frequently obscene. That was true of some of the stupendous fabrics in Southern India, such as Madura, Tanjore, and the like, and even of some of the buildings further north; and, therefore, people were apt to consider Indian art as something negligible compared with the more familiar, and superficially more attractive, forms of Mohammedan art which succeeded it. That was why it seemed to him of such value that an expert like Sir John should show not only what Indian art was capable of, but what it actually did. The slides that had been thrown upon the screen had depicted work of surpassing beauty. He was glad to notice that Sir John devoted a few passages to the examination of the Indo-Bactrian or Graeco-Indian school of sculpture, which was practised on the North-West frontier of India. As far as he remembered, when he first went to India, nearly forty years ago, those sculptures had only just been discovered. A perfect wealth of those beautiful sculptures was excavated, and they could now be seen in most of the museums of Europe. One of the most interesting features of those sculptures, to which Sir John had referred, was the conception which those who practised the art gave to the form and face of Buddha. Some of the illustrations of the form and face of Buddha which had been thrown on the screen that afternoon were comparable with the very finest Hellenic art, and were essentially Greek in character and appearance. That particular type of face which was always associated with Buddha, and which had gone over the world as the Buddhistic face, started from that time, and it had the extraordinary quality, to which the lecturer had referred, of seeming to express

more than any other sculpture of any other school in the world. That was a great achievement. He did not know what Buddha was like in the flesh, but it was a great thing that his religion, which was based on the highest spiritual conceptions, should be identified with a form and face as spiritual and remarkable as that which the Graeco-Indian sculptors produced. The lecturer had then referred to what he called the Gupta period, and had thrown upon the screen some reproductions of the wonderful frescoes from the Caves of Ajanta. He hoped, from the apparent perfection of the pictures, that the work of preservation which had been going on for a long time was being successfully conducted, because when he went there many years ago some of the frescoes were in an appalling condition. It was not from want of interest on the part of the Native State or the ruler of the Native State in which they were situated—Hyderabad; in fact, the Nizam had always done everything in his power; but neglect, the passage of time, and some unscientific attempts at restoration had undoubtedly done great harm. He believed that now the frescoes were properly looked after. After looking at some of the pictures, particularly of the female form, that had been thrown upon the screen, who could deny that Indian art had an imagination, a sense of beauty, a command of form and a spirituality that placed it on a very high level among the plastic arts of the world? There was only one other subject to which Sir John Marshall had alluded to which he would like to refer, because it brought back a memory. Sir John threw upon the screen a photograph of that wonderful demi-lune window in the mosque of Sidi Sayyid at Ahmedabad. In his opening remarks he had introduced Sir John Marshall as one who had done more than anybody else to preserve and to cherish the ancient monuments of India. Personally, he recalled the first occasion on which he went to that mosque with his old colleague and secretary, Sir Walter Lawrence, who was present at the meeting. They arrived at the mosque during an Indian afternoon, and they became aware of the existence of that wonderful piece of tracery in stone. They found that the mosque had been converted into what was known as a cutcherry, *i.e.*, an abominable institution in which clerks kept their papers and conducted their ordinary administrative business. That exquisite mosque was piled high with these atrocious evidences of modern civilisation, and in order to see the beautiful window it was necessary to go round to the back of the building. It contained a hole as big as one's fist which had destroyed the perfection and delicacy of the work. He very soon had the paper contents of the building removed and, he hoped, burnt; the clerks were turned out, and the building was handed over to Sir John Marshall. It was now one of the best known and most frequently visited, as it was one of the most lovely relics in the world. Sir John Marshall had been at work so long in India that he had almost become an ancient monument himself, although his appearance belied that reputation. He was sure, however, Sir John would allow him to thank him very much for the lecture he had delivered, and to say on behalf of all present that they were very grateful to him not only for giving the lecture, but for having selected the particular subject that he had dealt with.

Sir Charles Bayley, G.C.I.E., K.C.S.I. (Chairman of the Indian Section Committee), in seconding the motion, desired to say how glad the Committee were to welcome Lord Curzon. The interest his Lordship had taken in practically every subject connected with India was well known to all. There was, however, a singular appropriateness in his presence at their meeting, because no one had done more than he had done for Indian art. Noble specimens of that art were scattered all over India, and it was not too much to say that, of course with notable exceptions, they were unknown to the world at large and too often neglected. It was Lord Curzon who first really directed attention to Indian archæology as a whole, it was he who established the Archæological Department, and it was to him that India owed Sir John Marshall's appointment. It had been a particular gratification to the speaker to be present at this meeting because it had been his privilege to serve in several parts of India in which magnificent specimens of Indian art existed which had now been thoroughly explored and in many cases put into a condition in which they would endure as a delight to all interested in India and its art and as a monument to the care of the Government of India. He was in Central India when the excavations at Sanchi were begun, and it had been his good fortune to accompany Lord Curzon to the splendid Mohammedan buildings at Mandu. Later he had been in Bihar when the wonderful buildings at Pataliputra were brought to light, and the exploration of the still more wonderful remains of the Buddhist University at Nalanda was commenced. For all these works and for those at Taxila and many others, India owed an immense debt to Lord Curzon and Sir John Marshall.

The motion was carried unanimously.

Lord Askwith, K.C.B., K.C., D.C.L., said that as Chairman of the Council of the Royal Society of Arts, he desired, on behalf of the Society, and particularly of the Indian Section, which Lord Curzon had always supported, to express their thanks to him for his kindness in attending a meeting of the Section as an old friend. The lecturer had only touched upon the fringe of Indian art; and he had not alluded much to the Greek, and still less to the Persian and the Scythian and the British influence upon Indian art. He would remind the meeting that Lord Curzon as a young man approached

India through Persia, Afghanistan and other countries, and, therefore, knew something about their art and possibly of the manner in which they influenced the art of India in a geographical way. He trusted that when lectures were given in the future before the Society by Sir John Marshall upon other phases of Indian art, they would have again the opportunity of welcoming Lord Curzon in the chair. At a later stage of his life Lord Curzon went back to India as Viceroy, and nobody could complain that he did not act as a practical man. He had shown on the present occasion that he also acted as an æsthetic man, and he even pushed his æsthetical feeling to the point almost of brutality, when, in the interest of art, he ejected the sacred files of officials! The lecturer had said, that the Imperial period of Indian art was in the Gupta period, introduced by the combination of the practical and the æsthetic sense. It might be that Lord Curzon's Viceroyalty which, when the history of India was written, must ever remain as one of the most remarkable features of recent times, would be heralded as the beginning of a new movement in Indian art, partly by the preservation that he accorded to its ancient monuments, and that his influence might have a more far-reaching character than could even at present be dreamt of. He was sure all present would express, by acclamation, their thanks to Lord Curzon for presiding over the meeting, and at the same time express the hope that they would again see him occupying the same position in the near future.

The Chairman, in reply, said: I will only thank you in a sentence for your kind reception of me, and Lord Askwith in particular, for the words he has employed. I hope you will now allow me to retire to much less attractive pursuits in an office with which I am temporarily connected.

WALNUT PRODUCTION IN CHINA.

The walnut found in China is the *Juglans*, a botanical genus of some 10 species, and is the same as that met with generally in temperate regions of the Northern Hemisphere. The species best known in China is the *Juglans regia*, which has a wide growing area extending from Greece to the Himalayas and on through Asia into extreme Northern China. These trees, growing in many parts of China bid fair to become of increasing commercial importance, except where transportation is still primitive and the natives have not yet realised the value of the nuts, thus preventing them from entering into the commerce of the country.

Walnuts are not systematically cultivated, the trees being planted generally to furnish shade, and no attempt seems to have been made to improve the stock by grafting or other methods. However, in many parts of the country farmers may be found who have from 25 to 100 trees.

According to information received by the Far Eastern Division of the United States Department of Commerce and published in the official "Commerce Reports," the principal provinces from which walnuts are obtained in China are Chihli, Shantung, Shansi, and Honan. In Chihli the centres of the trade are the Changpingchow district, some 30 miles north of Peking and the Lanchow and Changli districts on the Peking-Mukden Railway. The nuts from these districts rank as the best and are shipped abroad from Tientsin. In Shantung walnuts grow wild for the most part, little or no effort being made to cultivate them. The best come from the southern districts, but they do not run even, a large proportion of bad being mixed with those of better quality, thus compelling the buyer to exercise great care in his selection and inspection. In the other northern Provinces the walnuts grow wild quite generally. They are cultivated somewhat systematically in a few districts, Fenchow-fu in Shansi Province producing nuts of good quality. Hunan and Szechwan lead among the central and western Provinces, with Hankow as the principal port for handling. These nuts, which are of good grade, are exported mostly as kernels.

A firm exporting walnuts from the ports of Tientsin has estimated the production of four Provinces of North China as follows: Chihli, 2,000 tons; Shansi, 3,000 tons; Honan, 3,200 tons; and Shantung, 500 tons. These figures, however, are in some cases merely guesses. based on information received from dealers. No estimates have been found for the other walnut-growing sections of China. The same authority states that he is not aware of any walnuts being grown in Manchuria. It seems that the term "Manchurian walnuts" is a misnomer used largely in connexion with those shipped from Tientsin.

In the Chinese trade there are three well known varieties, the double-shelled, medium hard-shelled, and paper-shelled. The double-shelled variety is the lowest in price. The medium hard-shelled is produced in largest quantities, while the paper-shelled is not extensively cultivated.

As with most of the commodities exported from China, the producers of walnuts receive but little of the profits. At the beginning of the harvest season, the local dealer contracts with the farmers for the crop, and later sends it to Tientsin, Hankow, and other ports, where wholesale dealers take it over.

The shipping season commences in September, with the soft-shelled nuts coming in about a month earlier than the hard-shelled varieties. In North China most of the nuts are sent to Tientsin and are exported either in the shell or shelled. The shelled are known as wet-cracked or dry-cracked. In the former case they are dipped in hot water before being cracked.

a method generally adopted in the interior and one that has proved very objectionable. Foreign exporters prefer to arrange for cracking to be done in the cities, where dry cracking is generally adopted and can be properly supervised. Shelled nuts are transported to the shipping ports in thin wooden boxes holding from 50 to 100 pounds. Before final shipment, however, they are carefully repacked in cases of three sizes, small, with a gross weight of 32 pounds; medium, 68 pounds; and large, 73 pounds. Walnuts in the shell are shipped in bags with a gross weight of 102 pounds.

MINERALS IN YUNNAN.

Yunnan is rich in minerals, but owing to lack of capital, and inadequate means of communication mining enterprises there are not prosperous. According to the Chinese Government Bureau of Economic Information, the principal minerals mined are tin, copper, antimony, zinc, lead, silver, gold, iron, and coal.

Tin is very abundant, especially in Kokiuchang where more than 7,000 tons are produced annually. From 1917 to 1918, the price per picul was about $150. Later, owing to the decrease in the value of gold, one picul of tin was only valued at $70. As a result, the business of the mines in Kokiuchang decreased. One of the difficulties encountered is the high cost of production with an inferior quality of output. Also, in consequence of its poor colour, the tin has to be refined a second time in Carlton.

Copper is also found in great abundance in Yunnan. There are copper mines in Tungchuan, Imen, Yungpeh, Weise, Likiang, Lungling, Chungtien, Lunan, etc., which have been operated successfully. The largest organisation engaged in mining is the Mining Service Company.

Antimony mining in Yunnan was at first carried on by the Pao An Company, capitalised at $300,000. Its refinery is situated at the Chi Chen railway tation on the Yunnan-Annam Railway. Theres are three modern furnaces. In 1915 antimony was valued at $1,200 per ton. In 1917 the price was considerably less, selling for $260 the picul. The antimony mines are so far from the market that the cost of transportation of a ton of antimony to Hong Kong is enormous. Many antimony mines have been opened and a number of companies have failed.

Zinc is found in Loping, Yunnan, Tung Chwan Yua, Chootung, etc., and was sold at $40 the picul in 1915-16. At that time the zinc merchants all made large profits. Many of the smaller zinc mining enterprises have since been closed.

There is more lead produced annually in Yunnan than antimony. The principal lead mining companies are the Tungchwan Mining Service Company, the Fu Lung Lead Factory of Lamping, the Ming Kiang Factory of Tengyueh, Lou Ma Factory of Lutien, Yunnan and the Mao Mai factory of Langkiung. Lead sold at $26 in 1915-1916, but now brings in $9. A certain amount of lead is consumed in Yunnan in the manufacture of lead foil, while the greater part is exported to Hong Kong. Owing to the decrease in price, lead exports will cease, as the markets for zinc enterprises have since been closed.

In Yunnan lead mines containing a little raw silver are commonly called silver mines. Formerly the Pei Mao Factory of Kaihwa, the Ming Kiang Factory of Tengyueh, the Lou Ma Factory of Lutien, etc., were noted for their production of silver. Now nearly all of them have suspended work.

Gold is found chiefly in Kaihwa, Likiang Weisi, Chengtien, Tengyueh, etc. At the present time only the Kiang Ma Gold Mine in Weisi is operating. Its output is about 200 taels of gold annually.

There is no district in Yunnan without iron mines. Brown iron is the most plentiful. The present iron mines in operation are at Weisi, Yulung, Tengyueh, Hoking, Mengtsze, Pingi, Anning, etc. The price of iron increased considerably during the European War. The only difficulty is that the method of refining in use is an old one and the quality of the output is inferior.

Coal mines are abundant. Owing to difficulties of communication, only sufficient coal is produced annually to be consumed by the province. The largest amount of coal is produced in Mengtsze, and the districts along the line of the Yunnan-Annam Railway. Recently the price of charcoal has risen so high that most of the residents prefer to use coal as fuel. All the coal mining companies are more prosperous than previously.

In addition to the above mentioned minerals there are others, such as brimstone, sulphur, etc., which are also very abundant.

HAIR-NETS.

Hair-nets were originally a product of the northern part of Austria, whence they were shipped to all parts of the world. An American firm once discovered in a package of hair-nets a scrap of a Chinese newspaper referring to hair-nets, and began to make enquiries. It was subsequently found that German firms were manufacturing hair-nets in China and shipping the product by mail to small towns in Germany and Austria, whence they were distributed as German products.

The demand for the Chinese product resulted in an abnormal development of the industry in Shantung, and Chinese firms undertook the manufacture themselves.

The business to-day, according to the Chinese Government Bureau of Economic Information, is largely in the hands of Americans. The hair as collected in the interior is usually too coarse to be used in manufacture before chemical treatment. Consequently, it is shipped to Europe and America, where it is softened, made thinner and dyed. It is then returned to China to be woven into nets. The process of manufacture is rather one of tying knots, and the work, which requires a great deal of

patience and dexterity, is done by women and children. After manufacture the nets are brought to the so-called factories for inspection and repair. They are spread out on a sheet of paper, when the defects are easily discernible. This work is sometimes done in America, or by foreign women in China.

The value of hairnets exported from Chefoo was, according to the Customs returns, Tls. 2,804,008 in 1920 and Tls. 7,078,332 in 1921. Exports from Shanghai, which, until the end of 1922, had the advantage of foreign post offices, were Tls. 4,133,343 in 1921. The principal producing district is Shantung, with some exports from Tientsin. The chief consumers are America, Great Britain and France.

THE SWISS EMBROIDERY INDUSTRY.

The embroidery industry of the St. Gall district is, perhaps, of special interest to British textile manufacturers, as most of the raw material is supplied to Switzerland by the United Kingdom. According to the annual report of the Commercial Secretary to H.M. Legation at Berne, the embroidery industry is passing through a severe crisis which has been going on since the beginning of the war. The whole of the Canton of St. Gall is almost entirely dependent on the embroidery industry. Its development since the eighteenth century was built up on the existing original hand loom spinning and weaving then general, which was gradually in part replaced by mechanical spinning. A large number of St. Gall hand loom spinners and weavers then turned to embroidering. The water is very suitable for bleaching purposes, and there is a demand for winter work among the agricultural population. Formerly labour was very cheap, and there seemed to be a natural aptitude for the work. From being purely a home industry, it gradually became a factory industry except in the Canton of Appenzell. There it still remains a home industry. In the Canton of St. Gall, out of a population of 295,000 some 40,600 are employed in the embroidery industry. In the Canton of Appenzell, out of a population of 70,000, nearly 14,000 are similarly employed. Altogether, there are 7,963 hand looms and machines, and 5,116 mechanical machines in use, making a total of 13,079 machines.

The large embroidery houses are the centre of the industry. Usually they confine themselves to the processes of designing, patterning, selling, packing and exporting. The Canton maintains a school of designers, where pupils pay a nominal fee, and evening classes are held. Head designers earn salaries of frs. 12,000 to frs. 15,000 per annum. The machine proprietors are entirely separate concerns and receive their patterns from the large embroidery houses. The cloth is supplied by the embroidery houses and the yarn by the machine proprietors.

The Swiss manufacturers can register their designs at Berne and during the last 20 years approximately 5,400,000 samples have thus been registered. This figure probably only represents one-quarter of the total number of patterns designed. The present fashion has vastly changed, and has eliminated the elaborate lingerie, blouses, etc., which were one of the main articles of the St. Gall industry. A return of these articles into fashion would in some measure bring back prosperity to the industry.

In the United States, home-made staple shuttle machine goods have increasingly competed with the Swiss exports. Brazil also now manufactures cheap staple goods. Besides these new competitors, there are the old-established industries in Plauen (Saxony), Nottingham, St. Quentin and in the Voralberg (Austria).

A scheme is now being formulated for State aid to the embroidery industry. A society is to be formed with a capital of 1½ million francs. The half million is to be subscribed by the industry, and the remaining million by the State.

Subventions are also to be granted by the the State, the municipalities and Cantons interested also contributing a share. The funds are to be administered by a company working under the style of the *Treuhandgesellschaft*. Banking principles are to be adhered to, and the bulk of the money is to be used in granting mortgages. The Federal Council has offered to lend five million francs on condition that the embroidery industry takes shares to the extent of a minimum of half a million francs. This sum has been found so that the *Treuhandgesellschaft* has been assured.

According to official statistics, Switzerland exported during the first nine months of 1922, 203 tons of chain-stitch embroideries valued at frs. 6,865,000. In addition, Switzerland exported during the same period 2,457 tons of flat stitch embroideries valued at frs. 101,441,000, her best customers being the United States of America, the Dutch Indies and Great Britain, in both types of embroidery.

DEVELOPMENT OF WATER-POWER IN SWITZERLAND.

In his Report on the Economic and Financial Conditions in Switzerland, the Commercial Secretary to His Majesty's Legation at Berne states that the development of power stations has suffered from the general crisis prevailing throughout Swiss industries.

There are now 25 stations in Switzerland, either completed or in course of erection, furnishing more than 20,000 h.p. each. The following stations have been put into service within the last fifteen months (up to December, 1922):—

Broc (Canton of Fribourg).—Built by the Entreprises Electriques Fribourgeoises. Equipped for 24,000 h.p., to be extended later to 30,000 h.p.

Lungernsee (Canton of Unterwald).—Central Swiss Power Company. Actually equipped for 18,000 h.p.

Klosters-Kueblis (Canton Grisons).—Belongs to the Grisons Power Company. Furnishes 25,000 h.p. to be extended to 55,000 h.p.

Amsteg (Canton of Uri).—Swiss Federal Railways. Equipped for 68,000 h.p., of which 54,400 h.p. are being utilised at present for traction purposes on the Gothard and other recently electrified lines.

The following stations are now in course of construction :—

Barberine (Canton Valais).—For the electrification of the first division of the Swiss Federal Railway system. To furnish seven million kilowatt-hours during the winter 1923-24. To be finally equipped for 68,500 h.p.

Waeggithal (Canton of Schwyz).—Belonging jointly to the North East Swiss Power Company and the town of Zurich. Two stations of an aggregated power of 140,000 h.p.

Chancy-Pougny (Canton of Geneva).—On the Rhône. Belongs to the Société des Forces Morices de Chancy-Pougny. To be completed in 1924. 43,000 h.p.

Davos-Klosters (Canton Grisons).—Belongs to the Grisons Power Company. 30,000 h.p. To be completed (first stage only, of 20,000 h.p.) in the autumn, 1924.

Champsec-Bagnes (Canton Valais).—"Société d'Energie Electrique du Valais." First stage, 7,000 h.p.

The question of erecting a power station of 80,000 h.p. at Rupperswil (Canton Argovie) and at the Etzel (Canton of Schwyz) is being examined by the Swiss Federal railways.

Concessions have recently been granted to the Central Swiss Power Company for the erection of a 50,000 h.p. station using the waters of the Seelisbergsee (Canton of Uri), to the St. Gall and Appenzell Power Company for the utilisation of the Mutten Lake (Canton Glaris), and to a company contemplating the utilisation of the water-power of the Upper Tourtemagne Valley (Canton Valais). Another project for the construction of a 135,000 h.p. power station at Sion, utilising the water of the River Dixence, has just been submitted to the approval of the Valaisian Cantonal Government.

The amount of energy supplied in 1922 by the Swiss power stations has remained inferior to that of 1921 and especially of 1920. It is estimated that the yearly supply of energy supplied by Swiss stations amounts to approximately 2,000 million kilowatt hours. The energy furnished and consumed by isolated stations and the Federal railway power stations, totals 700 million kilowatt-hours. The sum total of utilized energy in a year is, therefore, 2,700 million kilowatt-hours, or approximately 750 kilowatt-hours per inhabitant.

The yearly export of energy is estimated at 350 million kilowatt-hours.

THE CHINESE COMPRADOR.

The following particulars regarding the Chinese comprador are based on a Report furnished by the United States Consul-General at Tientsin :—

The comprador is the medium of dealing between foreign firms and Chinese merchants and dealers, and is one of the most important factors in China's foreign-trade relations. Ever since the beginning of foreign intercourse in China, the comprador in a foreign firm has been indispensable. Barriers of language and social customs made the employment of the comprador a necessity and, as he has become virtually the manager of the foreign firm, his responsibilities and duties have increased. Formerly the character and probity of the comprador was unquestioned, and he occupied a unique position in trade circles. The word of a comprador was accepted and defaulters were seldom encountered. However, exploitation of Chinese credit and money by unscrupulous foreigners, with the consequent loss to the comprador, has tended to increase the number of defaulting Chinese. Where formerly oral contracts served, legal documents and bonds are now in practice.

Compradors must possess capital, a knowledge of business, and an extended acquaintance among the Chinese. There are two main classes of compradors—bank and merchandise compradors—whose functions are quite similar. The duties of the bank comprador are to transact business for the bank ; to look after all monetary matters, such as receipt and payment of money and the collection of cheques, drafts and notes ; to offer advice to the bank regarding the condition of the local market ; to compile commercial information ; and to recommend, control and guarantee the Chinese staff of the bank. The merchandise comprador must guarantee the firm's Chinese customers, advise as to market conditions, assist in obtaining business, and, in general, act as a go-between and as the Chinese manager for the firm in its relations with the Chinese business public. The contract of the comprador generally allows him one-half of one per cent. commission on all business done, based on the c.i.f. value of the goods sold. If the volume of business is exceptionally large, the commission is only one-fourth of one per cent.

The comprador system has its advantages and also its drawbacks, but for the present the comprador is an indispensable factor in the foreign trade of China. The longer a firm has been doing business in China, the less it should be obliged to depend upon the comprador. However, practically every foreign firm in China employs native salesmen, who to all

intents and purposes are compradors. The written contract which is now in vogue is based on the principle that the comprador must guarantee the commercial and financial standing of all Chinese firms introduced by him to the foreign firm, which is practically the same as the old verbal contract. But the legal protection afforded by the written contract and the sense of security obtained have done much to standardise the position of the comprador and to prevent misunderstandings detrimental to trade relations. In the development of the foreign trade of the new China the comprador will be a greater factor than in the past.

RUBBER PRODUCTION IN INDO-CHINA.

Rubber production in Indo-China is entering a stage where the quality and quantity produced will demand attention. The older plantations are now run by experts, brought from the Dutch colonies, and modern plants are turning out a product that is inferior to none. Up to the present time, writes the United States Consul at Saigon, all the rubber produced has been sent to Michelin in France, or to Singapore, where it is graded with local rubber and sold as a Singapore product.

The Indo-China production has been so unimportant that there has been no planters' association, or guaranteed export grades. This condition is being remedied and the Saigon exporters are now confident that they have a uniform and superior product for exportation. It is stated that Indo-China enjoys an advantage over other Eastern rubber producing countries by reason of the fact that the depth of the soil of Cochin China is greatly superior to that of Java and Singapore. The terrain is rolling, devoid of stone, and can all be cultivated, while land in Java is very rough. Also, land in Cochin China is covered only with bamboo and can be quickly cleared and placed under cultivation. This land can be had in large tracts from the Government on concession. Another great advantage lies in the total absence of the deadly root disease that is found in Java, and the fact that the white ants, which devastate other rubber-growing states in the world, are unknown in Indo-China.

The production per acre of the Xatrach plantation in Indo-China is given as 548 kilos for 1920 and 504 for 1921.

MANUFACTURE OF PAPER FROM COCONUT HUSKS.

Another material has been proposed for use in the commercial manufacture of paper. A company in the Philippines has recently begun the manufacture of desiccated coconut, and large quantities of husks result as waste products from the process. It is estimated that the total annual quantity of waste husks is from 350,000 to 400,000 tons, and it is claimed that these husks can be used for paper making, rope making, and other purposes.

There is some doubt, however, writes the United States Manager of the Philippine District Office in Manila, as to whether the cost of preparing the husks for paper making will make their commercial use possible. Certainly it would be impracticable to ship them in the crude form. The company now producing them states that the cost of drying husks, flattening them into rolls, and wrapping and baling them in hydraulic presses into bales of about 100 kilos each is $19.80 per metric ton (2,204.6 pounds). The expenses of loading, taxes, insurance, and freight bring the total cost of the husks to $37.50 per ton, c.i.f. New York or Boston.

If the husks are to be used for paper stock, therefore, it will be necessary to convert them into pulp near the mill from which they are a by-product in order to save expense in transportation. Even then it is questionable if the pulp could be produced at a figure which would allow it to compete with wood pulp and other kinds of pulp now used for paper making.

When the husks are to be used for other than paper making purposes they are dried, 60 per cent. of water being removed in the drying process. Then the dried husks are broken down into coir fibre and corky pulp, which is a by-product. There are two parts of coir fibre to one part of corky pulp. The coir fibre is said to be useful for rope making, filling mattresses, etc., and corky pulp for insulation purposes.

MINERAL WAX PRODUCTION IN POLAND

Poland possesses the only commercial deposits of mineral wax (ozokerite) in Europe. They are located principally in the Boryslaw oil region in Galacia, though smaller deposits have been found in the neighbouring Stanislawow oil region. Polish geologists report the discovery of rich deposits in the Truskawiec region, and a Polish corporation has undertaken the development of these new fields.

According to data collated by the United States Bureau of Foreign and Domestic Commerce, wax mining in Poland dates back to 1860. The work was commenced by Polish and French corporations, but at the present time most of the capital is in the hands of a corporation controlled by a Vienna bank. Early statistics show that in 1876 production reached 8,750 tons, and up to 1888 the yearly production ranged from 8,000 to 9,000 tons. The production has since been on the decline on account, it is stated, of serious restrictions imposed by the controlling authorities.

The following production figures, for specified years, show the decline that has taken place in the industry :—

	Tons.		Tons.
1809	5,420	1914	810
1899	7,740	1915	59
1910	2,150	1920	380
1913	1,580	1921	260

As production decreased, especially during the war period, prices increased.

The colour of the wax ranges from dark green to black, depending upon its purity. The average grade of mineral wax melts at 62° C., and is easily purified. Until a recent date the raw material was exported, but now it is being refined by a Polish concern.

In 1920 Poland exported 660 tons, divided among the following countries: Germany, 260 tons; Austria, 220 tons; Switzerland, 90 tons; United States, 40 tons; England, 30 tons; Czechoslovakia, 20 tons. In 1921 the exports decreased to 195 tons, of which 100 tons went to Austria, 75 tons to Germany, and 20 tons to Czechoslovakia. The high prices tended to decrease the foreign demand, and exportation was also hampered by smugglers, who mixed wax with paraffin and sold it as the pure product.

GENERAL NOTES.

Institute of Metals.—The autumn meeting of the Institute of Metals will be held in Manchester from September 10th to 13th. The second annual autumn lecture on subjects of practical interest to those engaged in the non-ferrous metals industry will be delivered by Lieut.-Col. Sir Henry Fowler, K.B.E. He will deal with "The Use of Non-Ferrous Metals in Engineering." The following communications are expected to be submitted :—E. A. Bolton, M.Sc., "The Cause of Red Stains on Sheet Brass"; H. W. Brownsdon, M.Sc., Ph.D., F.I.C., Note on "Brinell Hardness Numbers"; H. I. Coe, M.Sc., "The Behaviour of Metals under Compressive Stresses"; Hikozô Endo (Sendai, Japan), "On the Measurement of the Change of Volume in Metals during Solidification"; Ulick R. Evans, M.A., "The Electrochemical Character of Corrosion"; Marie L. V. Gayler, M.Sc., "The Constitution and Age-Hardening of the Quaternary Alloys of Aluminium, Copper, Magnesium, and Magnesium Silicide"; D. Hanson, D.Sc., C. Maryatt, B.Sc., and Grace W. Ford, B.Sc., "Investigation of the Effects of Impurities on Copper. Part I.—The Effect of Oxygen on Copper": H. Douglas Ingall, M.Sc., "Experiments with some Copper Wire: Cohesion a Function of both Temperature and Cold-work"; A. H. Mundey, and C. C. Bissett, B.A., B.Sc., B.Met., Note on "The Effect of Small Quantities of Nickel upon High-Grade Bearing Metal"; A. H. Mundey, and John Cartland, M.C., M.Sc., "Stereotyping"; Hugh O'Neill, M.Met., "Hardness Tests on Crystals of Aluminium"; Albert M. Portevin, (Paris), and Pierre Chevenard (Imphy), "A Dilatometric Study of the Transformations and Thermal Treatment of Light Alloys of Aluminium"; R. C. Reader, Ph.D., M.Sc., Note on "Effects of Rate of Cooling on the Density and Composition of Metals and Alloys"; E. L. Rhead, M.Sc., Tech., and J. D. Hannah, "Crystallization Effect on Galvanized Iron Sheets"; Professor P. Soldau, (Petrograd, Russia), "Equilibrium in the System Gold-Zinc (based on Investigations of Electrical Conductivity at High Temperatures)."

Industrial Decoration for Women.—The Chinese Government Bureau of Economic Information reports an interesting departure to encourage women who invest in industries or industrial banks or help to promote such enterprises. Such persons will hereafter be decorated with Phoenix Medals (Wen Feng Chang). These are of five classes and are to be awarded in the following way: 1st Class, for those who invest $200,000 or more of their own money or raise $1,000,000 or more from others; 2nd Class, for those who invest $100,000 or more or raise $500,000 or more; 3rd Class, for those who invest $50,000 or more or raise $200,000 or more; 4th Class, for those who invest $10,000 or more or raise $50,000 or more; 5th Class, for those who invest $5,000 or more or raise $25,000 or more. These medals have in the centre a green phoenix on a red disc with a golden margin, which is surrounded with four white peonies with green leaves and golden stems. The first-class medals will have 8 pearls studded between the peonies, the second-class 6, the third-class 4, the fourth-class 2, and the fifth-class none. They will be awarded to women industrialists upon the recommendation of the general chambers of commerce or the industrial boards of the provinces.

Standardisation in Industry in Norway.—According to the Report on the Industrial and Economic Conditions in Norway by the Commercial Secretary to H.M. Legation at Christiania, a plan has been drawn up by the Norwegian Industrial Union, for the advancement of standardisation in industry. It is proposed to establish one central committee, and sub-committees in all branches of industry where standardisation is possible, whose duty it would be to investigate all measures calculated to advance industrial standardisation, to supervise the administrative procedure on which standardisation must be based, and to propagate the adoption of a Norwegian standard. With a view to putting this plan into effect, the Union have applied for the sympathetic support of the Norwegian authorities, and for a State grant of kroner 30,000 per annum for three years. The Ministry of Commerce have recommended that half this sum should be granted.

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PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

THE VULCANISATION OF RUBBER.

LECTURE I. — *Delivered February 5th,* 1923.

By HENRY P. STEVENS, M.A., PH.D., F.I.C.

The term "vulcanisation" is applied to a change which rubber undergoes and by which its physical and chemical properties suffer subtle modifications. This change is generally brought about by heating with sulphur, or by treating with sulphur chloride in the cold.

In this first lecture I propose to deal with the change produced by vulcanisation as broadly as possible, reserving detailed consideration of some of the more important aspects to subsequent lectures. Briefly stated, rubber after vulcanisation (1) becomes less sensitive to changes of temperature, that is, it neither hardens in cold weather nor becomes sticky in the sun, (2) loses a part or the whole of its adhesive qualities, has a limited capacity for swelling in liquids and becomes "insoluble" in the ordinary solvents which dissolve raw rubber, (3) acquires improved physical properties—that is, the breaking strain and length at break are increased, and it recovers to its original shape more completely after distortion.

In one respect, it is deteriorated, for vulcanised rubber is more easily slit or torn. These remarks apply to rubber vulcanised with sulphur, and without other ingredients. The properties of the vulcanised product may be considerably modified by the incorporation of mineral and other substances, to which consideration will be given in a subsequent lecture.

The process of vulcanisation is accompanied by a chemical change, the sulphur, or the sulphur and the chlorine if sulphur chloride be used, combining additively with the rubber. The evidence for this will be given later. I will content myself for the moment with the statement that the progress of the physical effect produced by vulcanisation is accompanied with a progressive increase in the proportion of sulphur combined with the rubber—that is, sulphur which cannot be removed by extraction with suitable solvents.

It is important to remember that vulcanisation is a gradual process in all its manifestations. There are no sudden changes. Raw rubber passes imperceptibly into vulcanised rubber, and as the change proceeds, the properties become more and more differentiated from the raw material. The rubber becomes harder, less distensible and less affected by solvents, until eventually the stage of hard rubber or ebonite is reached, when the contrast between the raw material and the vulcanised product is greatest, and a substance is obtained differing widely from the raw material in almost every respect.

Many have the impression that raw rubber is a somewhat unstable and easily decomposable substance, which is stabilised and rendered useful in the arts by the process of vulcanisation. This is incorrect. Raw rubber, when properly refined, is a more stable substance than the vulcanised product, and is very little altered over long periods.

PRELIMINARY OPERATIONS INCIDENTAL TO VULCANISATION.

To appreciate the change which rubber undergoes in the process of vulcanisation, it is necessary to consider the properties and treatment of raw rubber in some detail.

Until the advent of plantation rubber the available supplies of the raw product were always marketed in a moist and impure state. These rubbers were invariably washed by the manufacturer, who used for this purpose washing or so-called crepeing

machines. These consist of two cast-iron rollers revolving towards one another at different speeds. The rubber, after cutting up and soaking in warm water, was passed repeatedly between the rollers in a stream of water

This treatment opened up the rubber and washed out the bark, sand and grit with which the material was contaminated The continuous lengths of rough surfaces sheet or crepe so obtained were then hung up to air dry. The native rubber thus prepared was frequently soft and sticky; firstly, because the rubber was derived from latices containing much resinous matter; secondly, because good latex was frequently adulterated with inferior sorts; and thirdly, because the rubber was partly decomposed owing to defective methods of coagulation and putrefaction in transit.

When a film or raw rubber is spread on cloth the surface is soft and adhesive, and to remedy this defect it may be dusted over with some fine powder. The use of sulphur for this purpose led to the discovery of vulcanisation. Some pieces of raw rubber dusted in this manner were heated by chance on a stove. The soft and sticky material was immensely improved by the heating process, and yielded a relatively hard, tough and resilient product. A simple method of vulcanising consists of immersing the rubber in molten sulphur. The latter gradually diffuses into or dissolves in the rubber and effects the change. Excellent physical results are obtainable in this manner, but the process is seldom suited to manufacturing conditions, as it does not allow the incorporation of other ingredients with the rubber, such as mineral matter, rubber substitutes, etc.

In order to produce an intimate admixture of rubber and other ingredients, including the sulphur, it is necessary to make the rubber plastic. This led to the discovery of the present method of milling rubber universally employed in rubber factories. The raw rubber, after washing and drying, is treated in roller machines built similarly to the washing or crepeing machines already described, but having hollow rollers fitted with inlet and outlet pipes, so that the rollers can either be heated by steam or cooled with water. These machines are commonly referred to as mills.

Alternatively, for some purposes, a "masticator" is employed. This consists of a single fluted roller moving in a casing. There are also so-called enclosed mixers, which can similarly be used to reduce the rubber to a plastic condition. The construction of all these machines have this in common that they consist of one or more rollers which crush or knead the rubber with suitable provision for heating and cooling.

The handling of the rubber at this stage is of great importance, as the milling or mastication modifies the physical properties of the rubber after vulcanisation. It is, therefore, necessary to give the process careful consideration. The effect of milling on the rubber will be conditioned by (1) the temperature and (2) the power consumption, and broadly speaking, the former should be adjusted so that the latter is at a minimum to produce the desired degree of plasticity. This entails the application of heat at the initial stage and subsequent cooling to prevent the temperature induced by friction from rising beyond 60 deg. or 70 deg. Cent. A higher temperature tends to cause oxidation and degradation of the rubber.

Much heat is engendered when a piece of cold rubber is passed between the rollers of the mill, and after three or four rollings with the rollers not too close together the temperature of the rubber rises to a greater degree than that of the rollers. The power consumption at this stage is considerable. It is, therefore, common practice to heat both the rollers and the rubber previous to milling so that the temperature of the rubber is raised to, say, 60 deg. Cent. as quickly as possible. The heat softens the rubber and so reduces the power of consumption. Water cooling is afterwards required to withdraw the heat developed during the later stages of the process.

On the other hand, the temperature must not be kept too low or the power consumption will be raised and the rubber damaged. These remarks must be interpreted with due regard to the raw material under treatment. Low grade native rubbers, now seldom met with, hardly require any treatment to render them plastic, and the temperature can be kept lower than for the better grades. Plantation rubber takes more power and will stand a higher temperature than wild grades. This may be attributed to the fact that the rubber is washed on the estate when in the form of a soft wet coagulum, whereas wild rubbers are drier and harder when received by the manufacturers than the wet coagulum on the plantations and take more power

on the washing machines with an equivalent saving of power on the mills.

In all cases the milling process causes some deterioration of the rubber which is subsequently compensated by vulcanising so that the physical properties are restored. If milling could be avoided, and the rubber fashioned to the required shape direct from the latex, vulcanisation would not always be necessary. In any case a much lower degree of vulcanisation would suffice. As, however, it is almost always necessary to render the rubber plastic, vulcanisation to the full extent must follow in due course, as this is the only means of restoring to the rubber those properties which it has lost in the milling. It is true that the physical properties of the vulcanised product may excel those of the original raw material. On the other hand, this improvement is only secured with a shortening of the life of the product.

Comparative Tensile Properties of Raw and Vulcanised Rubber.

It is interesting to compare the tensile properties of raw and vulcanised rubber. A strict comparison can be drawn in the case of plantation rubber or fine Para. The former rubber is available for testing in a clean dry state without a preliminary washing and drying which, as I have explained, is equivalent to a short milling. The latter can be obtained in suitable form by splitting up sections of a loaf of this rubber to give a test piece comprising several layers of superimposed films which are allowed to air dry. The following are the minimal, maximal and average figures of a number of samples of raw rubber which were tested :-

treatment with sodium phenate or cresylate, has been found in my laboratory to give products of unusually high tensile properties. In fact, prepared in this way, the rubber is comparable with a semi-vulcanised product as regards tensile properties.

The crepe specimens used were dense and free from holes. The samples for testing were chosen as nearly as possible 2 mm. thick and 25 mm. wide, which corresponds to a sectional area of 50 sq. mm. If the samples differed from 2 mm. in thickness the width was cut either wider or narrower so as to retain a cross sectional area of 50 sq. mm.

The tensile product figures obtained with rubber vulcanised by the Peachey process will not be equivalent to those obtainable by heat vulcanisation as the former process seldom gives a uniformly vulcanised product. There is always a tendency for the outer layers to be more fully vulcanised than the inner layers. This may account for the fact that even the maximal figures in the above table are appreciably lower than those obtainable with rubber, which has been mould cured in the ordinary manner. Thus, in the form of ring shaped test pieces an ordinary vulcanised rubber and sulphur mixing may give a breaking strain of 150 to 200 kilos, a length at break of nearly 10 units, and consequently a tensile product up to 2,000 units. Such rubber, however, is not permanent. To yield a reasonably permanent product the breaking strain would probably not exceed 100 kilos, the length at break a little over 10 units, and a tensile product of about 1,000 units.

It will be seen from the above figures that vulcanised by the Peachey process the maximal figures for breaking strain for plantation rubber do not exceed 50 kilos, the length at break 7.5 units and the tensile product something over 400 units. Vulcanised rubber test pieces can be obtained of the exact size and shape required, whereas raw rubber test pieces must be cut to shape and will

	Breaking strain, Kilos. per sq. cm.			Length at break (elongation), original length.1.			Tensile product.		
	Min.	Max.	Avge.	Min.	Max.	Avge.	Min.	Max.	Avge.
Raw rubber :—									
Fine Para	32.4	45.4	38.4	4.20	4.71	4.51	136	214	173
Plant, crepe	15.0	33.4	22.8	2.04	3.42	2.56	46	147	83
,, s.s.	5.2	14.8	8.5	4.62	7.08	5.91	29	119	61
Vulcanised rubber (Peachey process) :—									
Plant crepe	18.5	37.2	31.2	1.96	4.30	2.90	55	197	124
,, s.s.	17.0	50.0	37.1	5.60	7.52	7.01	112	425	303

Fine Para rubber gives the highest breaking strain figures, partly owing to the compact nature of the material, each film being very uniform and homogeneous. The method of preparation may also have some influence on the properties of the raw material. Thus, latex coagulated after

have a more or less irregular contour. This no doubt results in a lower breaking strain figure, a conclusion borne out by comparing the figures for the raw and vulcanised rubber in the above table.

It is noteworthy that the improvement produced by vulcanising is usually greater with plantation smoked sheet than with crepe, due probably to the former being smooth and more regular in shape than the latter. In no case did the increase in breaking strain of crepe rubber on vulcanisation exceed 150 per cent., whereas the smoked sheet rubber showed an increase in breaking strain of over 1,000 per cent. in one instance. The average increase was 37 per cent. with crepe and 298 per cent. with sheet. Improvement in the length at break figures was also greater in the case of the smoked sheet although the difference is not so marked as with the breaking strain figures.

Concomitant Changes in Physical Properties and Chemical Composition.

If we start with a milled or masticated Para rubber, with which sulphur has been incorporated, we find a gradual change in the physical properties as the period of heating progresses. The milled rubber is soft and plastic. A relatively short period of heating out of contact with the air at the ordinary vulcanising temperatures, say, 120 deg. to 150 deg. Cent., results in an elastic but very distensible product with low tensile properties. The percentage of combined sulphur (that is, sulphur which cannot be extracted with alcohol or acetone) is low, and may be in the neighbourhood of 1 per cent. On heating for a longer period the tensile properties improve, the length at break shows a tendency to recede to the neighbourhood of 10 or 11 units and the breaking strain rises to 40 or 50 kilos per sq. cm. The combined sulphur approximates to 2 per cent of the rubber.

As the heating is prolonged the breaking strain increases, and the length at break decreases until the maximum is reached of 150 to 200 kilos, and length at break of 9.5 to 10 units. The combined sulphur is then in the neighbourhood of 5 per cent. Further heating results in further combination with sulphur if a sufficient excess be present, the light yellow product darkens to a red-brown and becomes brittle, the feel is leathery, eventually a hard and elastic product is obtained (hard rubber or ebonite) and the combined sulphur reaches a maximum of approximately 32 per cent. of the raw rubber taken.

These gradual changes in tensile properties are accompanied by similar gradual changes in other physical properties as, for instance, the behaviour of the rubber to organic solvents. The effect produced is dependent on the condition of the raw material. Raw rubber varies enormously in its behaviour to solvents. Some varieties, such as the films of fine Para or plantation sheet or rubber obtained by the evaporation of the latex, "dissolve" slowly, being gradually dispersed in the solvent. The dispersion is preceded by considerable swelling. Plantation crepe rubber swells less and is more easily dispersed. Rubber, of whatever origin when milled or masticated, disperses readily without appreciable swelling.

Let us take mixtures of masticated rubber and sulphur which have been heated for varying periods as before, and immerse small pieces in benzine in test tubes, leaving overnight at room temperature. If the period of heating is very short the swollen rubber becomes gradually fluid, and on shaking the test tube the next morning the rubber is completely dispersed in the solvent. The longer the heating the less readily this occurs, until a stage is reached when the rubber, although much swollen, is no longer dispersed on shaking, but is merely broken up into a number of fragments which remain suspended in the liquor. In this condition aproximately ½ per cent. of sulphur is combined with the rubber.

When the heating is prolonged beyond this stage, there is a progressive reduction of the swelling with increased firmness of the gel. Prolonged heating results in the formation of hard rubber, which swells but little in a solvent provided a sufficiency of sulphur is present to convert the rubber into a relatively highly sulphurised product. As in all colloidal processes the action of solvents is largely controlled by the time factor. A specimen of rubber may be vulcanised to a degree which will not permit of dispersion when immersed in the solvent overnight. If, however, the test tube be corked and set aside for a few weeks, complete dispersion may take place.

The progress of vulcanisation may, therefore, be followed by any or all of the phenomena enumerated below :—

(1) Change in physical properties, in particular the tensile characteristics.

(2) The percentage of combined sulphur.

(3) Sol and gel formation.

These phenomena will now be discussed in some detail.

Determination of Tensile Properties.

The tensile characteristics of vulcanised rubber are most readily compared by ascertaining the elongation produced by the application of a given load, or the elongation may be kept constant and the load measured. Similar results could be obtained by compressing instead of elongating the test pieces, but such a system has not been developed to any extent, as the elongation method is more convenient and susceptible to more accurate measurement.

There are a few instruments by which the approximate resistance to compression may be determined. These consist essentially of a blunt pin which is forced into the mass of rubber against the resistance of a spring, and a reading is taken of the resistance offered by means of a spring dynamometer. The projecting pin must not rupture the rubber. The instrument (penetrometer) is placed on the sample of rubber, and the under surface from which the pin projects is brought level with the surface of the rubber. The softer the rubber the greater the penetration, the amount of which is read off on a dial. As would be anticipated, the more fully vulcanised the rubber the less the penetration. These instruments are useful for rough tests, for instance, of the hardness of a tyre tread, but are not suitable for accurate measurements.

For stretching tests the test piece may be either a strip or a ring, preferably the latter, as a strip of vulcanised rubber is not easily held by jaws or grips. As the rubber stretches, its sectional area decreases, and the thickness of the strip becomes smaller than the distance between the jaws, which results in slipping and tearing. Various modified grips have been tried, but none are really satisfactory; consequently strips are always cut dumb-bell shape, that is, thinner in the centre than at the ends. This results in several disadvantages—in particular, the stretch cannot be measured by the distance between the grips but must be marked off on the narrow centre part of the test piece; and, secondly, the rubber, on stretching, tends to "flow" from the thicker to the thinner parts, so that the actual cross-sectional area at any moment is uncertain.

For purely technical purposes the strip test piece may suffice, as comparative results are usually all that is required. For operating the ring test piece it is slipped over a pair of rollers which are gradually drawn apart. The "crushing" of the test piece is obviated by keeping the ring in movement by a positive drive on one of the rollers. The defect of the ring test piece arises from the variation in the relative lengths of the inner and outer circumference of the ring when stretched. This results in the rubber in the neighbourhood of the inner circumference being stretched more than that on the outer. Consequently, the inner is subjected to a greater strain.

This inequality of conditions may be partly overcome by reducing the thickness of the ring, and it is found that thin rings give appreciably higher breaking strains than thick ones. The error is mainly concerned with the breaking strain, that is, with the limiting figures for load and stretch and not with the intermediate figures. For most purposes it is usual to employ a ring with an internal diameter of 45 mm., and a sectional area of 5 by 4 mm. The ring test piece has this great advantage over the strip, namely, that the load stretch data can be automatically recorded as a curve. With this brief indication of the principles of testing appliances we will examine the load stretch curves of a vulcanised mixture of rubber and sulphur.

The Load-Stretch Curve of Vulcanised Rubber.

Fig. 1—A represents a typical curve of a mixture vulcanised to give maximal breaking strain. This corresponds to approximately 5 to 5½ per cent. of sulphur combined with the rubber. The load is measured vertically and the elongation horizontally. The characteristics of this curve consist in (1) the relatively small rate of increase in load for a given increase in elongation at the beginning, (2) a change-over period in the middle and (3) a final portion of the curve in which the conditions are the reverse of the first portion, that is, the relatively greater increase of load for a given increase in elongation. This final portion of the curve approximates more and more to a straight line. This characteristic has been studied and termed the slope, and is measured by the angle with the vertical. It is in the neighbourhood of 30 deg. to 35 deg., and shows relative small variation.

When a "pure" vulcanised rubber sulphur mixture is stretched or compressed, there is

no appreciable alteration in volume; hence the sectional area of a piece of "pure" vulcanised rubber when stretched is reduced proportionately to the elongation. If the original length be doubled, the sectional area will be halved and so forth. As such rubber may stretch to 10 times its original length before rupture, it is obvious that the sectional area will be reduced to one-tenth, and the breaking strain per sq. cm. will be

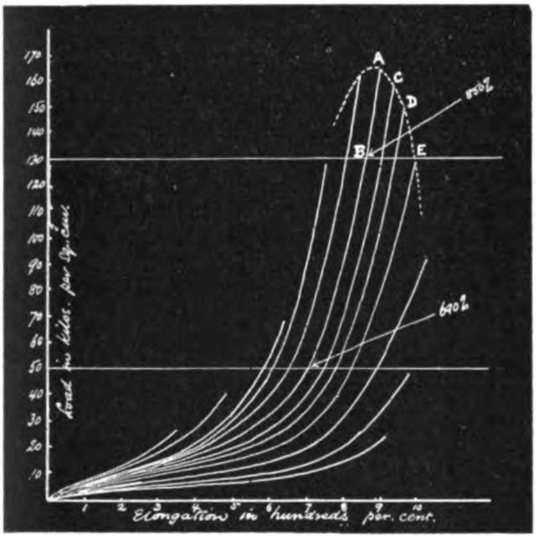

FIG. 1.

10 times as great if this were based on the sectional area at rupture of that of the original unstretched test piece.

The load stretch curves illustrated give the results based on a constant sectional area; consequently they do not actually represent stress-strain curves. If the actual stress-strain curves be drawn with the stress representing the load per given cross sectional area of the stretched specimen, we obtain a curve from which the characteristics above noted have disappeared. These actual stress-strain curves have been identified as quadrilateral hyperbolæ. Such a curve has two constants, and the relationship of these constants with the degree of vulcanisation and composition of the rubber await investigation. For technical purposes the original load-stretch curves have considerable value as they illustrate the typical behaviour of different types of rubber and different degrees of vulcanisation.

Confining ourselves at present to the "pure" vulcanised rubber we note the characteristic change in the relative rate of increase of load and stretch at the beginning and end of the stretching. As an example, if it is desired to obtain a stiff suspension with a "pure" rubber band it is obvious that the band must be elongated to four or five times its orginal length. A boy with a catapult of "pure" rubber cord will require to stretch the cord to near its full limit of elongation to propel the stone with high velocity. If the cord were stretched to half its maximal elongation a very low velocity would result.

In addition to the curve A in fig. 1, there are drawn a number of other curves. All these represent "pure" vulcanised rubber but vulcanised to different degrees. Those lying to the left of the curve A represent "overcures." The vulcanisation has been carried beyond the optimal stage and the curves are shorter corresponding to a lower breaking strain. The curves lying to the right of curve A represent "undercures." These also give lower breaking strains, but the loss is more gradual, or, in other words, the breaking strain increases as the degree of vulcanisation increases, until the maximum is reached, when the decrease in breaking strain is relatively rapid. This will be noted from the dotted line connecting the curve limits. These curve limits are to a large extent fortuitous, and a large number of determinations are necessary to ascertain the maximal breaking strain.

Of greater importance is the position of the curves relative to one another. Such measurements can be made with considerable accuracy. When the specimen is fully cured the measurement may be made at a load of 130 kilos per sq. cm. For weaker or less cured specimens 50 or 60 kilos may be taken. The actual position of the curve A is fairly constant for all first class crepe or sheet plantation rubber prepared by the ordinary processes. One investigator gives the figure of 890 per cent. elongation for a load of 130 kilos, that is a length of 9.9—original length of test piece taken as unity. Others have obtained a rather lower figure such as 850 per cent. These differences no doubt arise from fortuitous variations, as the conditions of the experiment, e.g., temperature, moisture content, etc., cannot be kept perfectly constant.

FACTORS INFLUENCING THE POSITION OF THE LOAD-STRETCH CURVE.

The following factors will influence the results:—

(1) The manipulative preparation of the test piece. This will include the condition of milling, vulcanising, etc.

(2) The proportion of sulphur.

(3) The age of the specimen, that is the period elapsing between vulcanisation and testing.

(4) The temperature during this period.

(5) The temperature during the test.

(6) The moisture in the atmosphere during ageing and testing.

For example, overmilling will give a rubber with a tendency to a greater elongation at a given load. An increased proportion of sulphur will tend to have the reverse effect, as it will act as a filler. In tests of this description it is assumed that ample sulphur is used, say, 7 to 10 per cent., so that vulcanisation proceeds at approximately maximal speed. The age of the specimen is of great importance. I have already stated that vulcanised rubber is not a stable product. Its life is dependent on (1) the quality of the raw material, (2) the conditions of treatment previous to vulcanisation, particularly the milling, and (3) the conditions of vulcanisation.

We need hardly concern ourselves with the quality of the raw article, but may assume that throughout we are handling a first-grade rubber, such as fine Para or plantation sheet or crepe. We will also assume that normal treatment has been given to the rubber in the preparation of the specimen. The life of the rubber will then depend on the degree of vulcanisation.

A specimen vulcanised to give the maximal breaking strain will age more rapidly than one less vulcanised. This follows from the fact that the changes which vulcanised rubber undergoes subsequent to vulcanisation resemble the vulcanisation changes themselves. Thus, just as the elongation at any given load is reduced by prolonging the period of vulcanisation it is also reduced by prolonging the period subsequent to vulcanisation, that is by ageing. Or again, as the elongation is reduced by vulcanising at a higher temperature, so also the elongation of the vulcanised rubber is reduced by ageing at a higher temperature.

This covers the fourth point enumerated above. But little is known as regards the effect of the temperature of the test piece when the test is made, but the results indicate an increased elongation for a given load with a rise in temperature.

The Measurement of the Vulcanisation Effect.

All these points serve to emphasise the gradual transformation characteristic of vulcanisation, and the changes which take place in the vulcanised products. The processes, in all cases, move forward by imperceptible stages. There is no sharp distinction between a raw and vulcanised product or between an unvulcanised, fully vulcanised or over vulcanised product. Consequently one is forced to fix on some arbitrary figure to define what is meant. Those who have studied "pure" vulcanised

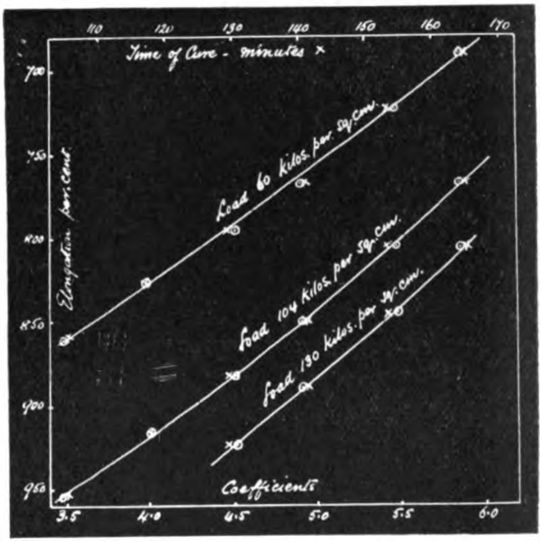

Fig. 2.

rubber have usually chosen the condition giving the maximal breaking strain, but, as I have pointed out, this figure is only ascertainable as the result of a large number of individual determinations which would be impracticable in most instances. Consequently, a standard curve has been generally adopted.

This curve is defined by the load-stretch curve which gives the maximal breaking strain taking the average of a large number of determinations with different specimens of rubber. To fix this curve it is necessary to give the elongation at a given load, or vice versa. Each investigator takes his own standard and vulcanises his specimens until they give the standard elongation at the given load, that is passed through the point B (fig. 1). Provided a given standard load (or elongation) be taken, the degree

or state of cure may be measured in terms of the tensile properties by noting the corresponding elongation (or load). The degree or state of cure may also be correlated with the period of heating at a constant temperature.

We are not justified in assuming that the degree of cure is proportional either to the elongation at a standard load or the time of heating, but if experiment reveals a simple relationship in either or both cases, we are provided with a better means of defining and measuring the degree or state of cure.

Figs. 2. and 3 give the curves drawn for sheet and crepe rubber respectively, the elongation being taken as the ordinates

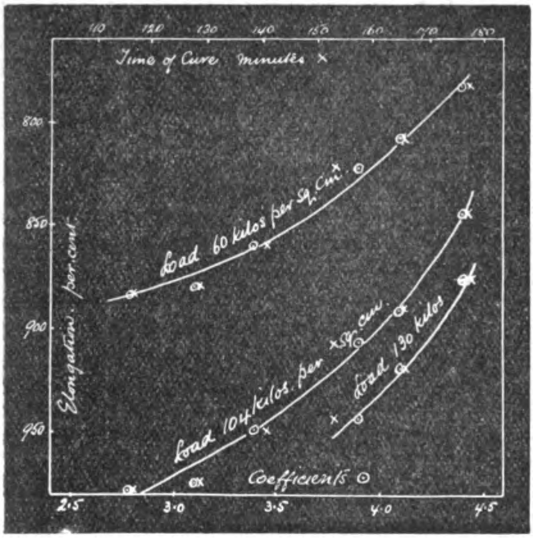

FIG. 3.

and the time of cure as abscissæ. The actual determinations are marked with a cross. In both figures the curves are drawn to give the elongations at various times of cure corresponding to loads of 60, 104 and 130 kilos per sq. cm.

Fig. 2 gives the results obtained for ordinary smoked sheet, and it will be seen that the curves are almost rectilinear. There is, however, a slight curvature which is not fortuitous. If straight lines were drawn in the place of the curves the correspondence with the observations would be appreciably less. It will also be noted that the curves are almost parallel, and show only a slight tendency to converge. It, therefore, follows that the elongations at any load between 60 and 130 kilos are approximately directly proportional to the time of cure, and consequently it is almost a matter of indifference whether we take the elongation at a given load or the time of cure as a measure of the degree of vulcanisation of the rubber. I may add that a similar series of independent tests in which the load required to produce a given constant elongation was determined gave exactly similar results.

If we turn to fig. 3 in which are drawn a similar series of curves for crepe rubber, it is at once apparent that the relationship of time of cure and elongation at a given load is more removed from direct proportionality than in the case of smoked sheet rubber. The curvilinear character is more pronounced and there is a greater tendency to converge. The curvature is greater at the higher elongations and smaller loads. The curvature obtained with crepe rubber shows considerable variation. Some samples of crepe rubber give curves which approach more closely to a straight line, while others, particularly when prepared from "matured" coagulum, show greater curvature.

There is no doubt that the curvature is to be associated with changes which take place in the coagulum subsequent to coagulation and previous to drying, for the longer the coagulum be set aside (matured) the greater the variations noted. This matter will be discussed later when dealing with accelerators. For the moment we are concerned with measuring the degree of cure, and, in the case of crepe rubber, it is obvious that if the elongations are to be taken as a measure of the state of cure, then the rate of cure is not constant but decreases with increasing time of cure. This is conceivable if the proportion of sulphur in the "mix" be restricted but the mix employed in the present experiments retains ample sulphur to allow the change to proceed without hindrance to a point beyond that to which it has been carried in these experiments.

VULCANISATION AS A CHEMICAL REACTION.

I shall later revert to other physical methods of measuring the degree or state of cure. I now propose to consider vulcanisation as a chemical process and to measure its progress by the rate at which the sulphur combines with the rubber. For this purpose we distinguish between the sulphur chemically combined and the free sulphur which is dissolved, adsorbed or otherwise retained mechanically by the rubber and removed by extraction with suitable solvents (boiling

acetone or alcohol). The rubber unextracted is held to be combined, and if calculated as a percentage of the rubber present is known as the coefficient of vulcanisation.

The late C. O. Weber was the first chemist to undertake a comprehensive series of experiments to acertain the relationship between the amount of combined sulphur (coefficient) and the time of cure. He mixed rubber with 10 per cent. of sulphur and rolled the compound into sheets 3 mm. thick from which he cut a number of strips. These were immersed in water in a beaker, which again was surrounded by water in an autoclave fitted with a thermometer, pressure gauge, etc., that is to say, a small self-contained vulcaniser heated from beneath. The vulcaniser was opened every half hour, a strip removed, the cover replaced and the tenperature raised again to the desired vulcanising temperature as quickly as possible. Fresh water was added from time to time to make up for that lost by evaporation.

The results were plotted, a separate curve being obtained at each vulcanising temperature. The curves showed curious irregularities, but as these appeared in different places for tests carried out at different temperatures, they were difficult to interpret, and more recent work has shown that these irregularities were due to experimental errors. The degree of error is surprising when one reads of the precautions Weber took. Probably vulcanisation in water is unsuitable, as the water in the beaker will take longer to heat up than steam, and the irregular currents in the beaker will cause irregular and uneven heating of the test piece. Also the type of vulcaniser head used was not such as could be easily or quickly removed and replaced. With a different type of head and using specimens wrapped in cloth and immersed in steam much more regular results can be obtained. However this may be, Weber carried his work far enough to show that the combination of rubber and sulphur proceeds in the same manner as an ordinary chemical reaction, and that the higher the temperature the more rapid the combination.

Weber's work was followed up later by others, in particular by Spence, who about 1911 to 1913 published a series of papers dealing with the rate of combination of rubber and sulphur during vulcanisation. The apparatus used consisted of a type of glycerine bath surrounded with the vapour of boiling xylene. By this method the temperature of the glycerine was kept very constant and correction for barometric pressure never exceeded 1 deg. Cent.

The rubber and sulphur mixture as a thin sheet was placed in small circular moulds immersed in the glycerine bath. This type of apparatus allows the time of heating to be accurately adjusted as the bath is heated up to the required temperature before the moulds are put in. These very quickly attain the temperature of the bath and as rapidly cool down when removed. In this way the irregular intervals necessitated by Weber's apparatus are avoided, that is, the blowing off of steam, removal of the digester head, taking out sample, replacing head and reheating.

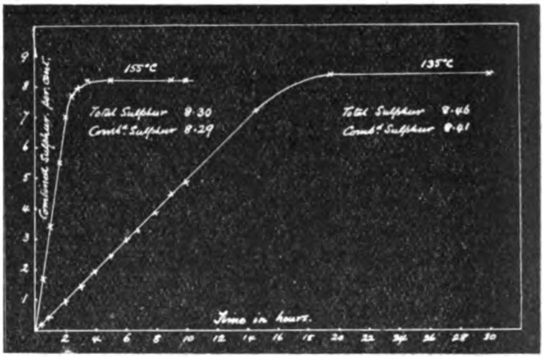

FIG. 4.

Fig. 4 shows two of Spence's vulcanisation curves. The time of heating is plotted as ordinates and the combined sulphur as abscissæ. It will be seen at once that the curves are rectilinear, the rate of combination of sulphur being constant throughout the whole operation except at the final stage, when the small amount of sulphur remaining retards the velocity of the reaction causing the curve to round off. When the whole of the sulphur has combined, no further change takes place and the curve becomes horizontal.

The two curves shown represent identical mixtures of rubber and sulphur vulcanised in the same way; the only difference relates to the temperature. The curve more approaching the vertical corresponds to the mixture vulcanised at 155 deg. Cent., while the more slanting curve to the mixture vulcanised 20 deg. lower. You will note that they closely resemble each other, but the higher temperature causes an increased

rate of vulcanisation—that is combination with sulphur—with the result that it takes a course more approximating to the vertical.

The series of figures obtained enabled Spence to calculate the temperature coefficient of the reaction. The velocity coefficient K $= \frac{x}{t}$ where x is the percentage of sulphur combined in any definite time interval t. In these experiments $t = \frac{1}{2}$ hour and the average figure for K for the whole series of determinations at 138 deg. Cent. was found to be 0.477 and for the determinations at 155 deg. Cent. 3·352, giving a temperature coefficient of 2.65 for every 10 deg. rise in temperature.

If you will now return to figs. 2 and 3 I will draw your attention to the divisions marked off at the bottom of the diagram. These give the coefficients of vulcanisation, that is to say, the percentage of sulphur combined with the rubber. The actual determinations are shown as circles. If these be plotted against the time of cure, we obtain a series of curves (fig. 5) corresponding to those of Spence, and confirmatory, although the curves are not quite rectilinear. I shall refer to this discrepancy in a later lecture. Reverting once more to figs. 2 and 3 it will be noted that the elongation figures, as plotted against the time of cure, practically coincide with those plotted against the coefficients so that the same curves are traced whether time of cure or coefficient be taken as the basis for determining the degree or state of cure. This, of course, follows from the fact that the curves in figs. 4 and 5 are rectilinear.

It follows, therefore that the amount of sulphur combined with rubber is directly proportional to the period of heating, but that the physical properties, as measured by the elongation for a given load, are only approximately proportional and show variations according to the type of rubber taken for the experiment. I would also remind you that I am considering the simplest type of rubber compound, that is, a mixture of rubber with excess of sulphur. If the amount of sulphur be reduced similar results are obtained provided there remains in the vulcanised specimen a sufficient residue of free sulphur. I have already shown that when a stage is reached at which but little free sulphur remains, the conditions are altered and the rate of combination with sulphur is retarded.

Under certain conditions vulcanisation will take place at relatively low temperatures, and fig. 6 illustrates a series of vulcanisation curves obtained by Spence at temperatures varying from 50 deg. to 75 deg. Cent. The ordinates represent per cent. of combined sulphur and the abscissæ time in days. You will note that the experiment was carried on for about three months, and during this period amounts up to 10 per cent. of sulphur combined with the rubber. The specimens were vulcanised in glycerine baths as before, the temperature being kept constant by means of suitable thermostats. The variation in temperature during the whole period of the experiments was less than 1 deg. Cent.

A glance at the figure shows that small variations in temperature would have rendered the results useless. The combined sulphur was estimated in the usual manner after removal of the free sulphur by exhaustive extraction with acetone. The rate of vulcanisation as shown by the combined sulphur is directly proportional to the time, and the curves exactly resemble those for vulcanising at the usual (technical) temperatures, such as 135 deg. to 145 deg., as shown

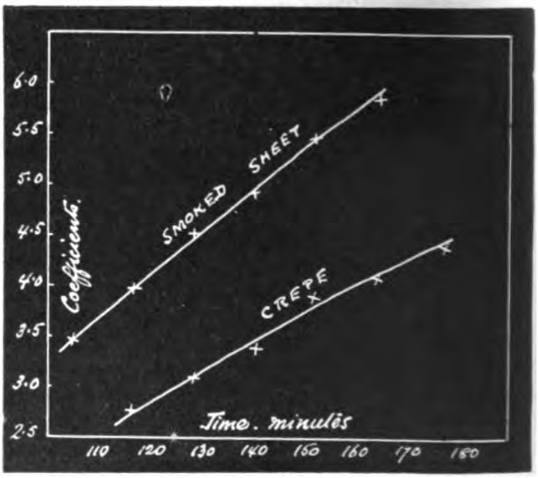

FIG. 5.

in fig. 4. Similarly, the results enable the velocity coefficient of the rubber sulphur reaction to be calculated from the data at these low temperatures. Figures fluctuating between 2.61 and 3.12 were obtained with an average of 2·84. This compares with 2.65, the figure obtained at higher vulcanising temperatures, a very close agreement, having regard to the experimental difficulties.

I should add that rubber, as ordinarily prepared, does not combine with sulphur as quickly at low temperatures as the curves in fig. 6 would indicate. This result was

obtained by increasing the amount of natural catalyst or activator naturally present in the rubber and concerning which I shall have more to say later. With ordinary plantation rubber the amount of sulphur combining in 90 days at 75 deg. Cent. was only 0·32 per cent., or at the rate of about 1 per cent per annum.

To sum up; we have considered vulcanisation as a chemical reaction taking place between sulphur and rubber, whereby a slow

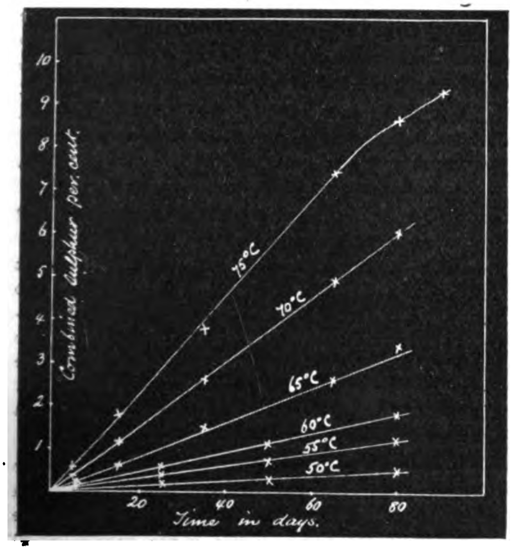

FIG. 6.

combination of the two proceeds under conditions corresponding exactly to other additive chemical reactions. While this combination progresses we have gradual changes in the physical properties. These physical changes, as measured, for instance, by the elongation of a test specimen under a given load, do not show the same simple relationship to the time of cure as the progress of vulcanisation considered as a chemical reaction.

We have so far considered the simplest possible mixture of rubber and sulphur, and have refrained from introducing ingredients which would complicate the process, such as the vulcanisation accelerators, sometimes regarded as catalysts. When we come to consider these more complex changes it will be found that the relationship of physical properties to state of vulcanisation, as measured by the amount of sulphur combined with the rubber, is still less uniform and that the physical properties may show appreciable variation independently of the chemical composition.

THE ROYAL SOCIETY OF ARTS AND POSTAL REFORM.

In Parliament on August 1st Lord Southwark asked the Government whether, in view of the unanimous opinion of the commercial community that an immense volume of postal communications would result from a return to penny postage, and of the unsatisfactory result of increasing the weight of letter packets carried for the minimum charge of 1½*d.*, they would consider the desirability of reducing the minimum charge for letter packets at home and to all British Possessions, Egypt, the United States of America and Tangier to a penny, with a corresponding reduction of the weight to one ounce for inland letters and half-an-ounce for other parts of the Empire, U.S.A., etc.

In the course of his speech, Lord Southwark said that, whilst his question dealt chiefly with our own Empire, he must add that cheaper foreign postage is urgently needed, too. He would like to commend to His Majesty's Government the splendid practical letter on penny postage from Lord Blyth which appeared in *The Times* on July 28th. They had every reason to be most grateful to Lord Blyth for the great services he had rendered in regard to cheap postage. In this connexion, Lord Southwark said he should like to draw attention to a matter which was not without interest. Sixty years ago it was publicly recognised in this country that our national wellbeing is linked up with cheap postage and enduring friendship with France. In 1864 the first Albert medal of the Royal Society of Arts was awarded to Sir Rowland Hill "for his great services to Arts, Manufactures, and Commerce in the creation of the penny postage, and for his other reforms in the postal system of this country, the benefits of which, however, have not been confined to this country, but have extended over the civilised world."

In the following year (1865), the second Albert medal was awarded to Napoleon III. "for distinguished merit in promoting, in many ways, by his personal exertions, the international progress of Arts, Manufactures and Commerce . . . . . and his enlightened commercial policy . . . . . in favour of British subjects." "These," remarked Lord Southwark, "are facts of outstanding importance at this juncture when we wish to continue our friendly relations and commercial intercourse with France."

Rather more than thirty years ago, Mr., afterwards, Sir John Henniker Heaton read a paper before the Royal Society of Arts on "Ocean Penny Postage and Cheap Telegraph Communication between England and all parts of the Empire and America." One of the speakers on the occasion was the late Mr. Hyde Clarke, who remarked that Mr. Heaton needed no apology for bringing the question before the Society, which, in the days when there was no London Chamber of Commerce, had a Postal Committee, and did its best to urge on postal reform. In his history of the Society, Sir Henry Trueman Wood tells us that the question of cheap international postage was actually taken

up as early as 1851, and that in 1852 the Council sent a deputation on the subject to Lord Granville, then Foreign Secretary. Sir Henry also points out that Sir Henry Cole, whose connexion with, and services to, the Society are so well known, "made his first mark in public life by his advocation of the introduction of penny postage and ever afterwards took a great interest in the development of the Post Office. . . . . It was largely owing to the exertions of Cole and (Sir Edwin) Chadwick, that the Society was so earnest at this time in promoting postal reform. The object was sought by every possible means; conferences were held, deputations were sent to successive Postmaster-Generals and to the Treasury; petitions were presented to the House of Commons, and in every way an agitation was kept up in favour of cheaper postal charges, the development of a parcel and sample post, the reduction of telegraph rates, the development of savings banks, the improvement of colonial and foreign postal communications and other charges—many of which have since been introduced, thanks to a large extent to the persistent recommendations of the Society.'

FUR TRADE IN KANSU AND SUIYUAN.

Furs, skins, and sheep and camel wool are the staple products of Kansu and Suiyuan. It is estimated that over fifty million dollars worth of such articles are produced annually by these two provinces. The furs or skins exported are generally divided into two kinds, the prepared and the unprepared. The prepared furs or skins are those which have been cut into the shape of a coat or a gown and these are generally disposed of in the home market. Those exported to foreign countries consist of pieces of skins without any tailoring work done on them.

The effect of the war in Europe was felt in the remote corners of Kansu and Suiyuan, according to the Chinese Government Bureau of Economic Information, and during the past few years there has been a depression in the fur and wool trade in both provinces. The market price of skins and furs dropped to an unprecedentedly low level, as few were bought by foreign firms.

Lately, foreign agents have again appeared in the Kansu and Suiyuan markets and have resumed their fur and wool exportation business. Quite a number of foreign firms have appointed agents in different towns and cities in the fur producing centres to collect these products for exportation. This has brought about a sudden rise in the price of furs, skins and wool. The market price of a picul of sheep's wool in Kansu, for instance, is now quoted at $8 and on the Suiyuan market it is sold at $12; but when brought to Tientsin it commands a price as high as $24. There has been a general rise in the market price of skins, hides and sheep and camel wool, owing to a brisk demand for such commodities by foreign firms.

THE MEAT INDUSTRY IN SOUTHERN RHODESIA.

By Loudon MacQueen Douglas, F.R.S.E.

Some time ago the Department of Agriculture in Salisbury, Rhodesia, which is under the direction of Dr. Eric Arthur Nobbs, issued a memorandum dealing extensively with the potentialities of the cattle trade in Southern Rhodesia. That was in 1921, and it was confidently expected at that time that a steady increase in the cattle of Rhodesia would take place. It was then anticipated that the total head of cattle in the country would be 2,095,000 in 1924, but it is too early yet to say that this anticipation will be realised. From a report of a Committee of Inquiry, just issued by the Legislative Council, it would appear, however, that steady progress is being made, as the total number of cattle, in 1922, in Southern Rhodesia was 1,754,144.

Obviously the time is approaching when it will have to be considered what is the best means of utilising so many food animals, and no doubt much technical skill will be called in, so as to develop the resources of Rhodesia as a cattle-breeding country. It is many years now since cattle-breeding started there and had to fight the terrible climatic diseases which then existed, but it is satisfactory to learn that this terror has to a large extent disappeared from the country.

It is the opinion of the Committee who drew up the report referred to that meat works can with great advantage be established in Rhodesia at the present time. They invite those interested in the meat trade to visit the country and inspect the cattle and investigate the possibilities of the export meat business. It is suggested that representatives who wish to make inquiries into the business on the spot should have their expenses paid by the Government of Rhodesia, and it is reckoned that the time which would be occupied in such inspections would be about two months. Instead of having isolated visits of the character indicated, it would surely be more advantageous to make up a party, and thus promote greater interest and freedom of discussion.

The report of the Committee of Inquiry is stated by the Chairman to indicate the nature of the problem in the cattle industry in Southern Rhodesia, and suggests, firstly, the lines of inquiry, and, secondly, the general policy which the Committee recommend the Government to adopt, so as to induce those interested in the European meat markets to look to Rhodesia as a new and not unimportant source of meat supply. The report deals with the proposal in a comprehensive fashion, and its principal conclusion is that every encouragement should be offered by the Government to those already concerned in, and conversant with, the intricacies of the frozen meat trade, to come and see for themselves the new field of Rhodesia, and to secure the obvious benefits of priority.

THE LOGWOOD INDUSTRY OF HAITI.

The cutting and exportation of logwood, for use in the manufacture of dyes, form one of the leading export industries of Haiti. For the fiscal years of 1916 and 1920, logwood was second in value among the products shipped from Haitian ports. The United States is the chief consumer for this dyewood and the bulk of logwood imported into the United States comes from Haiti.

The exports of logwood and logwood extract from Haiti during the three years ended 30th September, 1919-21, were as follows:—

Fiscal year ending Sept. 30.	Logwood.				Logwood extract (all to United States).	
	To United States.		Total.			
	Pounds.	Value.	Pounds.	Value.	Pounds	Value.
		$		$		$
1919..............	67,875,967	566,320	77,393,337	627,881	277,549	12,268
1920..............	188,403,515	2,264,601	242,157,599	2,844,329	7,019	23,882
1921..............	56,717,027	571,840	74,893,411	744,311	....	....

No statistics are available, writes the United States Consul at Cape Haitien, to show the extent of the logwood forests, but it is estimated that in the Bahon district alone, between 500,000 and 1,000,000 tons of the wood are available. The district named is situated about 25 miles south of Cape Haitien at the terminus of a railway (opened in 1916) connecting the town of Bahon with this port. Bahon logwood is clean and well matured, one ton of wood yielding about 500 pounds, or one barrel, of extract. The region near Cape Haitien has been largely worked over, and most of the wood now obtained from it is second growth. From 15 to 25 years should elapse before the second growth is utilised. The district near Port de Paix and Mole St. Nicholas, has yielded large quantities of logwood in recent years, of which the greater part went to the United States.

ANTIMONY INDUSTRY OF HUNAN.

Hunan has been producing antimony for over 20 years. Discoveries were made as early as 1897, and since that time new ones have been made yearly, according to reports from the United States Consulate at Hunan. The demand during the war greatly exceeded the supply, causing the price to soar to ten times its normal level. Hunan became a large exporting centre for antimony, and many mines and smelters sprang up all over the province. The termination of the war resulted in a cessation of the abnormal demand and the price went down to a very low level. In the course of 1922, a slight improvement became noticeable, and the richest mines, together with those that cost the least to operate, are now being worked to their full extent. During 1921 there were 921 mines in operation.

Deposits of antimony are abundantly and widely distributed throughout Hunan. The districts around Packing, Anhwa, and Sinhwa are particularly rich in their supply of this mineral. Hsikuangshan, a hill in the Sinhwa district, is called Antimony Hill, because of the richness of the deposits found there. The antimony ore of Hunan is of a very high grade, and is free from arsenic and other impurities. The antimony content of the ore runs from 20 to 65 per cent. Regulus exported by one company is stated to be 99.95 per cent. pure. The Herrenschmidt process is generally used in extracting antimony regulus. Since the demand for regulus has fallen off, antimony ore is manufactured into trioxide, commonly called antimony oxide.

THE CLOISONNÉ INDUSTRY.

Cloisonné manufacture in Peking dates back to the time of the Ming dynasty. Its very name in Chinese, Ching Tai Lan or Ching Tai Blue, suggests that cloisonné ware first made its appearance in Peking during the reign of the Emperor Ching Tai, of the Ming dynasty (1450-1456). In the days of the Ming Emperors, cloisonné ware was made for and used exclusively by the Imperial family and the public knew little about the article. In course of time, cloisonné manufacturing almost became a lost art.

In the later part of the eighteenth century, Emperor Chien Lung, of the late Tsing dynasty (1736-1795) issued an edict permitting the people to manufacture what had hitherto been the forbidden article, causing a sudden revival of the art. The works of the Chien Lung

period were divided into three classes: gold, silver and copper. Some of the work was of pure gold. Not only its structure but even the metallic partitions inlaid on the ware to form figures and designs were made of the same precious metal. The silver and the copper ware was made in the same manner, but of cheaper metal. The pigments and the enamel used were procured from certain mines in the country.

During the reigns of Chia Ching (1796-1820) and Tao Kwang Emperors (1821-1850) the art of manufacturing the ware again deteriorated. By that time a certain goldsmith by the name of Chia Yu-hua, whose occupation was to plate cloisonné ware, took pains to learn the art and after years of painful study he managed to become an expert. The ware produced by him bore close resemblance to productions of the Ming Imperial workshops. The industry was, however, restricted by the prohibitive price of the pigments and the enamel, which only one dealer in Peking knew how to make. Chia Yu-hua made further study and finally succeeded in discovering the secret of the making of these pigments. This cheapened the cost of production and a great number of articles were turned out by his workshops, where quite a number of apprentices were trained. Later the Teh Hsing Shun cloisonné factory was established in what is now the Legation quarter by the same proprietor, but it suffered serious financial losses during the Boxer Rising. After 1900 the establishment was reopened at Chang Yang Er Tiao and, according to a report of the Chinese Government Bureau of Economic Information, is turning out large pieces of excellent ware for foreign markets.

The Teh Hsing Shun wares have acquired international fame, and have won prizes at a number of international industrial exhibitions held in America, Japan and the Dutch East Indies in recent years.

TOBACCO CULTIVATION IN SHANTUNG.

Cigarette tobacco was first cultivated in Shantung in small quantities in 1915 by the farmers at Fangtze, to whom the British-American Tobacco Company distributed seeds for the purpose. A growing demand for this tobacco has extended the planting not only in Fangtze, but also in the neighbouring districts of Ankiu, Changyi and Changlo.

Tobacco of the American variety is preferred by the Shantung farmers for its superior quality. The seeds are sown early in April and the leaves are gathered in September. The average yield of each mow is estimated at 200 pounds. From a report of the Chinese Government Bureau of Economic Information, it appears that there are now about 200,000 mow planted in tobacco.

After harvesting the leaves are treated to a process of curing in specially constructed curing barns before they are sold. The British-American Tobacco Company, the Nanyang Brothers Tobacco Company and Japanese tobacco companies are the principal buyers. The local market is most active in October and the months immediately following.

Tobacco leaves are sold by the farmers to the exporters at forty cents. per pound and the net profits realised by the Shantung farmers from their annual tobacco crops are estimated to total about $9,000,000. A duty on the tobacco crop is fixed at so much per unit size curing barn. These barns are classified into three grades according to their capacity, and the duty is fixed on the scale of $12, $10 and $8 per barn.

GENERAL NOTES.

Journal of Scientific Instruments. The preliminary arrangements in connexion with the regular publication of the "Journal of Scientific Instruments" have now been made by the Institute of Physics in co-operation with the National Physical Laboratory. The special attention of those workers who have few designs for instruments is called to the act that the Journal is to serve as a medium of publication of detailed descriptions and critical surveys of the behaviour of such instruments. Original Papers or Laboratory and Workshop Notes dealing with the practical or theoretical aspects of scientific instruments should be sent to the Editor, Dr. John S. Sanderson, The National Physical Laboratory, Teddington, Middlesex.

Afforestation in Honan. — Since the establishment of a forestry bureau in Honan in 1917 much has been done by the Honan officials to promote afforestation in the province. The uncultivated areas in the neighbourhood of the Sung Shan have been marked out for this purpose. Acting upon the orders of the Ministry of Agriculture and Commerce, the Bureau, some years ago, instructed the magistrates to start a nursery in each district of the province. By the summer of 1919, it is said, nearly every district in the province had one or more of such nurseries. A set of regulations was promulgated with definite provisions governing the maintenance of the nurseries. The annual expenses of a district nursery occupying an area of fifty mow of land are limited to $600. The district authorities have been instructed to organise associations to help in promoting the work. A circular order was issued to the magistrates of the districts, enjoining them to plant trees on Arbor Day of this year, April 6th. Each district was expected to plant as many young trees as possible, the minimum number in each district not to be less than the total of its inhabitants.

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PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

THE VULCANISATION OF RUBBER.

By Henry P. Stevens, M.A., Ph.D., F.I.C.

Lecture II.—*Delivered February 12th*, 1923.

Correlation of the Coefficient and the Swelling of the Vulcanised Rubber in a Solvent.

We have so far considered only the tensile properties in some detail. We will now review other physical properties of vulcanised rubber. I have already explained that the behaviour of vulcanised rubber to a rubber solvent depends on the degree of vulcanisation, and provided vulcanisation is carried far enough to prevent actual dispersion of the rubber in the solvent, we have the vulcanised rubber swollen with solvent in a condition of approximate equilibrium with the surrounding medium.

The absorption of solvent by the rubber results in a small volume contraction; that is, the volume of the original rubber and the solvent is greater than that of the rubber after it has taken up the solvent. In the swelling process heat is developed which is connected with the change in volume. If rubber in a confined space is allowed to swell by taking up solvent, it will exert a very considerable pressure which can be measured by enclosing the rubber in a vessel with a semi-permeable membrane, such as a porous pot. This allows the solvent to penetrate to the rubber while confining the swollen mass. The porous pot, or plate, must, of course, be enclosed in a suitable steel cylinder to withstand the pressure. Working at a constant pressure, it is possible to measure the volume of a given weight of swollen rubber with a series of solvents, and to study the rate of swelling in each case.

A number of experiments on these lines were made by Posnjak with fine Para rubber, but no corresponding experimental data for vulcanised rubber are available. Some early experiments were made by Flusin with vulcanised rubber by the simpler method of allowing the rubber to swell in the solvent, and removing the latter as completely as possible. This method is not readily applicable to raw rubber, as the swollen gel in the latter case is very fragile, and the process is complicated by the dispersion of part of the rubber in the surrounding medium. Vulcanised rubber differs from raw rubber in that the swelling is not accompanied by appreciable dispersion, and there is, moreover, an approximate limit or maximum to the swelling, that is to the amount of the liquid taken up. This allows of the maximum being determined without working under pressure, as in Posnjak's experiments.

Flusin, in his original researches, drew a distinction between "active" and "inactive" solvents. The former have a considerable swelling effect, the latter very little. Ostwald noted that this grouping corresponded with the magnitude of the dielectric constant. The active solvents have low dielectric constants, and the inactive, such as water and alcohol, have high ones. By tabulating Flusin's and Posnjak's results, he found that the relationship existing between the maximum swelling effect produced by a given liquid and its dielectric constant, was of logarithmic character. Kirchhof has carried out a systematic investigation of the rate of swelling of vulcanised rubber in several solvents, and has compared the results with the coefficients of vulcanisation of the rubber specimens taken. His specimens form a series with coefficients from 1·2 to 6·4; that is, covering a full range from much undervulcanised to very fully and

overvulcanised rubbers. The results show that the maximum is quickly reached, although this is dependent on the temperature. You will note from the illustration (fig. 7) that the dotted lines corresponding

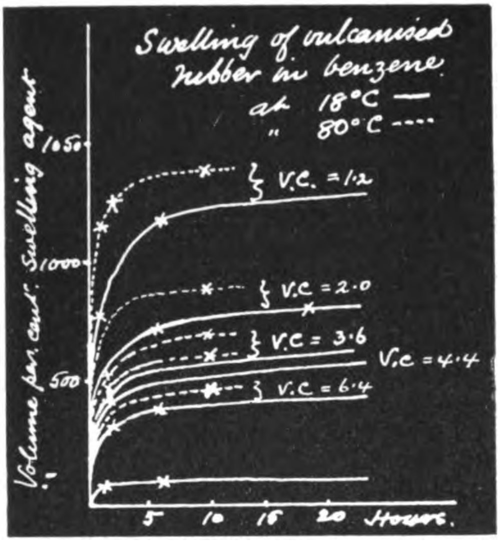

FIG. 7.

to 80 deg. Cent. lie higher than the continuous lines (18 deg. Cent.), whatever the degree of vulcanisation. Also, that the specimen showing the highest maximum corresponds to the lowest coefficient, and, as the coefficient increases, the swelling decreases.

The curves demonstrate clearly the connexion between the chemical constant, *i.e.*, the coefficient of vulcanisation and the physical condition of swelling. The figure gives the results for benzene. Similar results were obtained for carbon tetrachloride, carbon disulphide and benzene (light petroleum), but each solvent exerts its specific effect. In fig. 8 is shown the volume of solvent taken up plotted against the coefficient for four different liquids which swell vulcanised rubber rapidly. Swelling was taken to be complete in 24 hours at 18 deg. Cent. A second curve for carbon tetrachloride refers to one hour's swelling. These curves are reminiscent of figs. 2 and 3, particularly the latter, which gives the elongation at a given load plotted against the corresponding coefficients.

Kirchhof has published curves similar to those shown in figs. 2 and 3, and is of opinion that these have a great similarity to the swelling curves. If either the solvent taken up or the elongation at a given load be plotted against the logarithms of these values, he finds that the resultant curves are straight lines. There is, therefore, according to these researches, a close connexion between the chemically combined sulphur and the physical properties of distensibility, and also to swelling constants. Kirchhof suggests that distensibility may be regarded as expansion in one direction, while "swelling" corresponds to expansion in all three directions. The analogy is, perhaps, overstrained, as elongation does not represent a change of volume, expansion in one direction being compensated for by contraction in two others.

If the logarithmic relationship should be found to be generally applicable, a considerable simplification of the relationship of coefficient and physical properties will be obtainable. Kirchhof's elongation figures were for comparatively light loads—5 to 20 kg. per sq. cm.—and the experiments

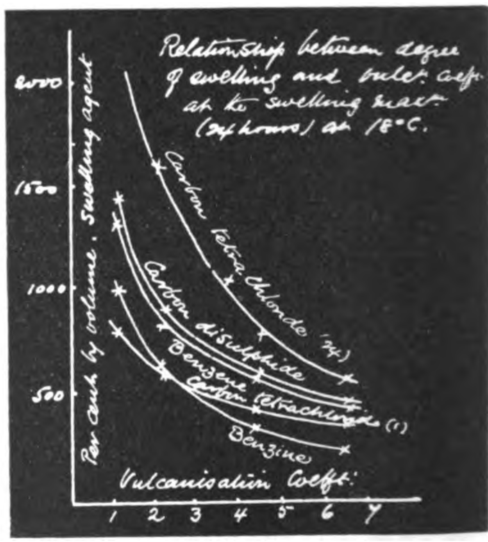

FIG. 8.

require extending to greater loads up to, say, 130 kg., as in the experiments illustrated in figs. 2 and 3. If this should confirm the relationship above noted, the maximum swelling, as well as the elongation under constant load, should provide means for ascertaining the degree of vulcanisation as based on the coefficient in simple mixtures of rubber and sulphur. My own experi-

ments indicate that the logarithmic relationship does not hold at higher loads and elongations.

In the above swelling experiments the rubber was immersed in the liquid solvents. The behaviour is quite different if the rubber be placed in the vapour of the solvent. The quantity of solvent taken up is much less as will be seen from the lowest curve in fig. 7. The quantity varies with the specific nature of the solvent, but is independent of the amount of combined sulphur.

DEGRADATION, PECTISATION AND REVERSION.

The ordinary heat vulcanising process has been represented as comprising two factors : (1) the chemical combination which results or accompanies a progressive change in the physical properties such as we have already discussed, inclusive of resistance to stretching and increased resistance to swelling when immersed in organic solvents ; (2) the effect of heat, which, apart from promoting vulcanisation, produces the reverse effect, namely, a softening of the rubber, rendering it more easily stretched and more susceptible to solvents.

The effect of heat on raw rubber is to weaken it, to destroy its "elasticity," and to render it plastic ; that is, the action is similar to that produced by mechanical working, although there are important distinctions. This characteristic is frequently described as depolymerisation, the hardening or "firming up" or pectisation brought about by vulcanisation being regarded as due to polymerisation. The term "polymerisation" has a definite meaning assigned to it by chemists. It involves the association of two or more molecules to form a larger molecule of the same percentage composition, depolymerisation being the corresponding splitting up of large molecules to give smaller ones.

As, however, we know nothing as to the size of the caoutchouc molecules, we can have no evidence whatever as to the formation of larger or smaller molecules ; it is obvious that the terms polymerisation and depolymerisation are incorrectly applied. The mere fact that, for instance, the viscosity of a rubber sol is lowered by mechanical treatment is no evidence that the size of the molecule is reduced. I, therefore, prefer to use other terms to express these changes. Suitable expressions are not easy to find, but I think the word "degradation" is preferable to depolymerisation and "firming up" or "stiffening" to polymerisation. In some of the changes referred to as depolymerisation, we have probably a partial decomposition of the rubber.

When a rubber sulphur is vulcanised by the ordinary heat process, the "firming up" effect immediately counteracts and masks any reverse change brought about by the heat of itself. If a piece of raw rubber be heated to a vulcanising temperature for quite a short time it becomes soft and sticky, but, if mixed with sulphur, this condition does not intervene. If the vulcanising be interrupted at an early stage the rubber, although but slightly vulcanised and weak, is not soft and sticky, as this effect is counteracted by the vulcanising. We will allow the heat to continue to act until most of the sulphur has combined with the rubber.

At this stage the vulcanising process slows down, and the remnants of sulphur combine so slowly with the rubber that the "firming up" effect so brought about is insufficient to counteract the softening or degrading effect of the heat, with the result that the rubber becomes apparently less vulcanised than before if judged by its physical properties alone. This effect, termed "reversion," is illustrated by reference to fig. 1 in the first lecture, which displays a series of load-stretch curves corresponding to a series of vulcanised rubber sulphur mixtures vulcanised for increasing periods and having increasing coefficients corresponding to the increased periods of vulcanisation.

This particular series was prepared from a mixture of one part of sulphur and nine parts rubber. The curves lengthen and become more vertical with increasing coefficients until a maximal tensile effect is reached as at A with a coefficient round about five units. Further heating results in more sulphur combining with the rubber, and the curves tend more and more to the vertical shifting regularly towards the load axis. The curves become shorter because the rubber becomes more brittle, but at the same time, it becomes harder, stretches less for a given load, and swells less when immersed in a solvent.

If now we take a mixture of rubber and sulphur containing, say, half the amount of sulphur, and heat it exactly as for the previous mixture, the sulphur combines with the rubber more slowly, but otherwise

similar changes take place and the curve moves steadily in the direction towards the load axis. As the excess of sulphur disappears, we arrive at a point when the vulcanising effect for a given period of heating is so small that it is neutralised by the softening effect of the heat *per se.* The load-stretch curve at this stage is, for example, given by the curve D. If the free sulphur were not exhausted, further heating would cause the curve to shift to C, thence to A, and so forth, instead of which the curve recedes to E, owing to the deficiency of sulphur.

The heat alone acts by degrading the rubber, and the softening results in greater elongation under a given load. "Vulcanising" beyond the stage given by the curve D, therefore, causes a reversion of the trend of the curve which takes up a position such as E. With longer heating the curve moves further and further from the load axis. It is, therefore, possible to prepare two specimens of vulcanised rubber from the identical raw rubber mixing which trace the same load-stretch curve but contain different amounts of combined sulphur.

There is, however, one point of distinction between these two curves; that from the "straight" cure will be longer indicating a higher breaking strain, that for the reversion effect shorter. This latter shows that longer heating acts so as to weaken as well as to soften the rubber. Later on, when we come to consider some of the modern accelerators, it will be found that identical curves can be obtained from specimens having different coefficients even for "straight" cures.

Tensile Strength and Breaking Strains.

Reverting to fig. 1, the end point of the curves corresponds to the breaking load and stretch at break. As vulcanisation proceeds the breaking load increases, and reaches a maximum as at A. It will be noted that the dotted line connecting the extremities of the curves is relatively flat at A. Consequently, a small error in the degree of vulcanisation will not affect the maximal breaking strain, except to a small extent. A larger error will be introduced by fortuitous variations in breaking strain given by different test pieces cut from the same specimen of vulcanised rubber.

I have not been successful in tracing the origin of these variations. Vulcanised rubber from its nature should be very homogeneous. One would not expect to find flaws in the test piece such as might be found in a metal casing. An examination of a broken ring sometimes shows cracks in one or more places, indicating that rupture was in progress in more than one position at the same time, so that had not the ring broken in one place, it would soon have given way in another. Low figures occasionally met with may be explained by assuming a slight flaw, or nick, to exist in the ring tested. Vulcanised rubber has a tendency to slit or tear, which is a phenomenon distinct from sudden rupture.

A small nick will start a tear, and an exceptionally low breaking strain figure will result. On the other hand, one occasionally comes across exceptionally high figures. One ring, out of half a dozen, will give a figure unapproached by the others. For this no adequate explanation is forthcoming. The figures for maximal breaking strains given by different investigators exhibit considerable variations which is surprising when the same type of machine and test pieces of the same dimensions are used.

Thus, de Vries has tabulated a large number of tests with the usual types of plantation rubber, the maximal figure for crepe being 150 kg., and for smoked sheet 155 kg. per sq. cm. Eaton gives a range of figures of a similar order. I have obtained figures somewhat higher, such as 170 kg. and 180 kg. per sq. cm., while Pelly also records figures of over 180 kg. per sq. cm. These apply to "pure" vulcanised rubber, and, as such rubber elongates to nearly ten times its original length before rupture, the actual breaking strain calculated on the cross-sectional area of the distended test piece will be 1,500 to 1,800 kg. per sq. cm., or something of the order of ten tons to the square inch.

Alternative Methods of Vulcanising.

We have hitherto dealt with one method of vulcanising, namely, that of milling the raw rubber till plastic, mixing with sulphur and heating. Provided a suitable temperature is reached and maintained, and provided also that the rubber is protected from air, a satisfactory change is brought about.

It is important to protect the rubber from oxidation, and this is effected in various ways. The compound may be enclosed in a metal mould; the mould is heated by placing in a pan where it is surrounded

by steam under pressure; or it may be heated by conduction between two hollow, steam-heated chambers, the mould having two, flat, parallel outer surfaces which are brought in contact with the flat surfaces of the steam chambers or platens.

Alternatively, the rubber may be retained by binding it with cloth and immersing in steam under pressure. If this method is to be applicable, the shape of the article to be made must be curved. Thus, a tube of vulcanised rubber may be made by covering a mandrel of the size of the bore of the tube with a layer of rubber, and then binding and holding the rubber in place by wrapping tightly with calico.

Some articles are manufactured by exposing directly to steam. Such articles are shaped as required, and placed on a layer of French chalk on a tray with a cover to protect them from drops of moisture, which may condense at some stage of the process. This is a cheap and rapid method, but the goods have not the smooth surface and sharp outline of those cured in moulds. I have also stated that rubber can be vulcanised by immersion in a sulphur bath. The technical effect is said to be very good, but the method is seldom applicable in practice.

The effect of vulcanisation, or a very similar change, can be obtained by means other than the action of sulphur and heat. Some substances that readily part with sulphur act in this way, for instance, polysulphides of the alkali metals. More interesting is the effect of "nascent" sulphur. Thus Peachey found that exposure of rubber to hydrogen sulphide, giving time for the gas to be absorbed, and subsequent exposure to sulphur dioxide, resulted in a reaction between the two gases dissolved in the rubber, the liberated sulphur combining with the rubber. We regard this as due either to the action of atomic sulphur, or to the intermediate formation of thiozone which then liberates sulphur in an active state. If this latter interpretation were correct, we should expect the liberation of two atoms of sulphur in the molecular state for every third atom which reacted with the rubber. As, however, the Peachey process can be carried out so that practically the whole of the liberated sulphur combines with the rubber, there does not appear any evidence favouring the intermediate formation of thiozone.

Bloch found that rubber could also be vulcanised in the cold by hydrogen persulphide. This, in theory, should split off one or more atoms of sulphur to combine with the rubber, at the same time liberating one molecule of hydrogen sulphide. I have carried out this reaction on several occasions, but in spite of precautions, have never succeeded in obtaining a vulcanising effect without the liberation of free sulphur. In the presence of acid, hydrogen persulphide is stable, and I found that, as long as acid was present, no reaction with the rubber took place; but, if the acid were neutralised, sulphur and hydrogen sulphide were liberated, and a portion of the former combined immediately with the rubber. The formula of the persulphide is perhaps not finally settled. Assuming it to be H_2S_4, as appears likely, we can picture decomposition into hydrogen sulphide and thiozone, which latter may then split into molecular and atomic sulphur and the latter combine with the rubber as in the Peachey process. From my own experiments, I concluded that the amount of sulphur liberated as such was always appreciably greater than that combining with the rubber.

Both these cold processes result in vulcanised rubber which closely resembles that obtained by heating with sulphur. There is practically no published data, but, from my own experiments, I conclude that the Peachey process, under favourable circumstances, yields a vulcanised product of greater tensile strength than is obtainable by the ordinary sulphur and heat process, and that a smaller proportion of combined sulphur is required to produce the same physical effect in the Peachey process than in the heat process. Of the Bloch process I have only the impression conveyed by the handling of small vulcanised films, but these appeared to be tough.

These processes take place in the cold, and consequently vulcanisation is not accompanied by the degrading effect of preliminary mastication when followed by heating as ordinarily employed for rubber vulcanisation. There are yet other substances such as the thiuram disulphides and certain other complex organic sulphides which readily part with some of their sulphur, and consequently vulcanise rubber. This type of vulcanising agent is more effective at a moderate heat. It also facilitates the combination of elemental sulphur with rubber—that is, it forms a group of vulcani-

sation accelerators which will be discussed later.

Sulphur is not the only vulcanising agent. Thus Boggs found that the allied element selenium produced an effect similar to sulphur. The process is of no practical importance. Sulphur monochloride has long been used as a vulcanising agent, particularly in the proofing industry, that is for the vulcanisation of thin layers of rubber deposited on fabric. The process was discovered by Parkes, and is commonly known as the cold cure, because the reaction takes place without application of heat. In fact, it is almost instantaneous, and it is necessary to dilute the sulphur chloride to a two per cent. solution in carbon bisulphide to moderate the reaction. This naturally retards the change, and, what is more important, carries the reagent into the rubber as the latter swells and takes up the solvent with the sulphur chloride dissolved in it.

Alternatively, rubber may be vulcanised by exposure to the vapours of sulphur chloride and carbon disulphide, the latter presumably to swell the rubber and facilitate the absorption of the sulphur chloride. These operations illustrate the disadvantages common to most cold cure processes, namely, the difficulty of keeping the reagents under control so as to produce a correctly vulcanised product uniform throughout. This type of vulcanising is, therefore, usually confined to thin films or sheets.

The following examples show the effect of vulcanising moderately thick sheets. A small piece of sheet rubber about ⅛in. thick was cured by treatment with hydrogen sulphide and sulphur dioxide, and a similar piece, mixed with ten per cent. of sulphur was cured in a mould. Each piece was then separated into three layers, an upper, middle and under layer. After extraction with acetone to remove free sulphur the residue was oxidised and the combined sulphur determined. The figures obtained were :—

	Upper. Per cent.	Middle. Per cent.	Under. Per cent.
Heat cured	3.96	4.06	3.91
Cold cured	3.43	2.86	5.71

The figure for the middle layer is slightly higher than for the outer layers in the case of the heat cured rubber, but there is a wide difference in the case of the cold cured rubber. Thinner layers of rubber will show smaller differences and sulphur chloride and similar processes are usually regarded as surface cures and suitable only for thin layers of rubber.

Sols and Gels of Vulcanised Rubber.

It is possible to vulcanise rubber in solution by practically all the known vulcanising processes. Some account of the methods available and products obtained will now be given.

When rubber is vulcanised with sulphur chloride' both elements combine with the rubber, and the mechanism has been subjected to several investigations. Weber was the first to carry out experiments on these lines. He worked with rubber solutions, that is, rubber sols in benzene, in order to be able to incorporate the sulphur chloride uniformly with the rubber.

It has been shown that vulcanised rubber containing relatively small amounts of combined sulphur swells but does not dissolve in the ordinary raw rubber solvents. Hence, if raw rubber could be vulcanised in sol form, that is, by heating a "solution" of the rubber in a solvent, the vulcanised rubber should gradually separate as a gel from the solvent. For such an experiment it is necessary to take a solvent which boils at a temperature above that necessary for vulcanising.

I chose xylene, and heated a solution of rubber with 10 per cent. of its weight of sulphur in a flask in an oil bath, stirring the contents from time to time. After heating for an hour or so, rubber began to deposit on the sides and bottom of the flask. The heating was continued for two or three hours, and the liquid poured off. The separated rubber was found to consist of a vulcanised gel. The recovered rubber behaved as if fully vulcanised, and had a coefficient of about four units. Part of the original rubber remained dispersed in the fluid portion and was recovered. It was weak and adhesive, but contained a small amount of combined sulphur.

Experiments were next tried with benzene, and the necessary temperature maintained by enclosing in a sealed vessel. This was placed in the vulcaniser and heated. When removed at the end of the operation and examined, it was found that no gel had separated, the whole contents consisting of a viscous fluid, which, while warm, could be poured into a mould where it set to a transparent yellow gel of uniform appearance.

On spontaneous evaporation of the benzene a film of vulcanised rubber was obtained which could not be redissolved in benzene in the cold.

Further research led to the following conclusions. Vulcanisation in sol form is subject to the same agencies as vulcanisation in a dry state; that is, the rate of vulcanisation is increased by raising the temperature, prolonging the time of heating, increasing the proportion of sulphur, inclusion of accelerators, etc. It is also subject to the concentration of the rubber and the specific nature of the solvent.

The physical properties of the recovered rubber show that some degradation of the rubber takes place, particularly when vulcanising at low concentrations. The heating under these conditions is prolonged with an adverse effect on the rubber. For this reason it is a great advantage to use accelerators, the more powerful the better; in fact, it is possible to produce vulcanised gels on these lines at very moderate temperatures or even in the cold when set aside for some time. The efficiency of some of the most active of low temperature accelerators can be judged in this way, but allowance must be made for the specific effect of the solvent which may vary with different accelerators.

If the concentration of the rubber sol is very low, say, one or two per cent., the liquid gels slowly, but as the concentration of the rubber increases, *e.g.*, ten per cent. (with sufficient excess of sulphur), the gelation is more rapid, while with higher percentages, *e.g.*, 20 to 50 per cent., the product, when taken hot from the vulcaniser, is too stiff to pour, and is, in fact, gelled. A ten per cent. solution can usually be diluted with more solvent to any desired extent when taken fresh from the vulcaniser, but when once it has gelled it can no longer be dispersed in more solvent.

The diluted sols are very sensitive to light. A sol which would remain liquid for weeks or months in the dark will gel in a few hours on exposure to diffused light. If placed in the dark again it slowly liquefies, but can be again gelled on re-exposure to light. These changes can be repeated a number of times. It is, however, doubtful how far this peculiar sensitiveness to light is connected with the vulcanised state, as Porritt has reported that a solution of raw rubber can be gelled if exposed to light in a sealed tube, and I have noted somewhat similar behaviour with a five per cent. solution of raw crepe rubber in benzene which had become thin and mobile after some years in a dark cupboard. On exposure to light for a time no change took place, and I lost interest in the specimen. However, some weeks later the window cleaner, in the course of his duties, shifted the bottle, and when replacing it I found the whole was a stiff gel. I replaced the bottle in the dark cupboard, and to-day it is mostly fluid, but contains some ropy portions which settled to the bottom, but are dispersed on shaking the whole. I shall continue to keep a watch on this interesting specimen.

When a film of rubber is first deposited from a vulcanised sol it has a soft, weak and undercured feel, although the coefficient may indicate a substantial degree of vulcanisation. On setting aside, the film gradually improves, and will eventually harden and perish, if the original state of

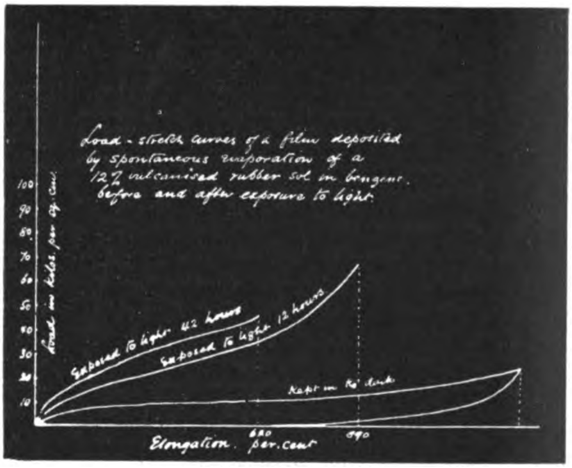

FIG. 9.

vulcanisation was too far advanced. This interesting hysteresis effect is parallel to the changes taking place in the original sol which tends more and more to gel when set aside, and just as this latter gels much faster on exposure to light, so the dry rubber film obtained from the gel ages much more quickly in the light than if kept in the dark. The effect of light on films obtained by the evaporation of the solvent from vulcanised rubber gels is shown graphically in fig. 9. This gives

the load stretch curves for a film before and after exposure to light.

The inferior physical properties of the freshly prepared dry films are undoubtedly caused by the degrading effect of the heat treatment. This has already been discussed in the case of ordinary vulcanised rubber when speaking of "reversion." It applies with greater force when considering vulcanised sols and gels because the effect of heat is more pronounced when the rubber is swollen, or dispersed, and the firming up effect of the vulcanising change is retarded. It was found, for instance, that a ten per cent. rubber sol vulcanised only half as fast as the dry rubber sulphur mixing. The temperature employed for vulcanising in sol form should be as low as possible. With rubber sols vulcanised in the cold, or at a low temperature, the hysteresis effect is hardly noticeable, and very weak rubber sols give stiff jellies which yield rubber of excellent physical properties after evaporation of the solvents.

Cold Vulcanised Gels.

Similar gels are obtained by the so-called cold vulcanisation processes, that is, by the Peachey method (H_2S and SO_2), Block's reagent (H_2S_4) and Parke's process (S_2Cl_2). The last-named has been most investigated, being much the oldest.

Most of the work done has been carried out to ascertain the combining proportion of sulphur chloride and rubber, for which purpose the rubber sol was treated with a large excess of sulphur chloride. Immediate gel formation took place. This gel was subsequently purified and analysed. But few experiments have been recorded as made with small proportions of the reagent and at considerable dilutions. If this be done, a graduated series of vulcanised products are obtained, beginning with products which do not gel on setting aside. Although still fluid these may show considerable increase in viscosity. There is no sharp distinction between this thickening or stiffening of the sol and the formation of a true gel.

The concentrations necessary to produce a gel depend to a great extent on the condition of the original raw rubber taken for making the raw rubber sol. If the raw rubber be untreated—as, for instance, a plantation first latex crepe—a five per cent. sol in benzene is ropy and difficult to handle. If rubber be taken which has been milled to a moderate extent, such as would be employed for ordinary rubber mixing, the five per cent. sol flows easily and appears homogeneous. Ten grms. of such rubber dissolved in 150 cc. of benzene and shaken with 25 cc. of a one per cent. solution of sulphur chloride in benzene gives a fluid which gels in one or two hours. If the proportion of sulphur chloride be halved no gelation takes place although the liquid becomes more viscous.

As an example of a more highly vulcanised gel 50 cc. of a ten per cent. rubber sol in benzene is shaken with 60 cc. of a ten per cent. sulphur chloride solution in benzene. Thickening sets in immediately, and in a few minutes the whole has gelled completely. The sulphur chloride sols and gels are much more stable if kept in the dark; even then the highly vulcanised gels change, the mass contracting and part of the solvent almost free from dissolved matter is expelled. Graham termed this type of change syneresis.

There is another type of syneresis which is brought about by exposure to light of less vulcanised gels. The first effect is to cause liquefaction, which is followed by the deposition of a solid or gel on the sides and walls of the vessel. The deposition is not distributed uniformly but forms in irregular masses much in the way that crystals sometimes separate from a solution in nodular forms. If the rubber be very severely milled, so as to cause greater degradation and a less viscous raw rubber sol, a correspondingly higher concentration or higher degree of vulcanisation is necessary to cause the mass to gel. In fact, the effect of milling the raw rubber is far more pronounced when the rubber is cold vulcanised "in solution" than when vulcanised by the sulphur and heat process, as in the latter the effect of the milling is largely obscured by the effect of heat.

It would seem, therefore, that it should be the aim in carrying out technical operations to conduct these in such a way as to degrade the rubber as little as possible. Unfortunately, mastication or milling is generally essential in order that other materials may be incorporated with the rubber, and to render the mass plastic enough to handle in the subsequent operations. The heat treatment can, however, be modified in various ways, and the lower the temperature, and the shorter the period

of heating, the better will be the physical results obtainable.

VULCANISING AGENTS OTHER THAN SULPHUR.

Before passing on to the study of accelerators and corresponding ingredients, I should mention the work of Ostromislenski, who claimed to have vulcanised rubber with agents other than sulphur or sulphur-containing substances. As the properties of vulcanised rubber are not exactly definable, and as in most respects, the difference between raw and vulcanised rubber is one of degree and not of kind, it follows that there are cases where it is difficult to say whether the product obtained by the action of some reagent on rubber is properly termed a vulcanised product and the process vulcanisation.

Thus, rubber can be chlorinated. The product is quite unlike raw rubber, and may be said to resemble vulcanised hard rubber in some respects. Moreover, a very resistant varnish termed "Duroprene" is manufactured in this way. Yet it would not be correct to describe the change as vulcanisation for the product differs widely from what may be regarded as a typically vulcanised rubber as obtained by heating a rubber sulphur mix.

Ostromislenski obtained products which, perhaps, sufficiently resemble the typical vulcanised rubber to be regarded as vulcanised, although the physical properties, and particularly the durability, were so deficient that the process is of merely theoretical interest.

There are two types of reaction, both heat vulcanisations. In one, the effect is obtained by the use of nitro-aromatic substances in conjunction with litharge; in the other by means of organic peroxides, particularly benzoyl peroxide. The mono-nitro derivatives have no appreciable vulcanising effect, but the dinitro, and particularly the trinitro derivatives, *e.g.*, trinitrobenzene, in the presence of litharge, are capable of yielding a product resembling a very inferior vulcanised rubber. Benzoyl peroxide gave products of inferior physical properties, but the change proceeded rapidly at relatively low temperatures, so that the product was light in colour. As the degree of vulcanisation was increased, the products passed through the usual stages of solubility and insolubility in the ordinary solvents. The rubber was, however, relatively weak and rapidly deteriorated and perished when stored.

NATURAL ACCELERATORS.

If raw rubber be purified, and most of the odd seven per cent. of non-caoutchouc matter be removed, we obtain a product which cannot be vulcanised by the heat-sulphur process, or, in any case, vulcanises extremely slowly. If we put back into the rubber the substances we removed, we restore to it its capacity to vulcanise. We can carry the matter a stage further by separating the extracted ingredients and trying the effect of each, and, if we do so, we find that the greater part of the non-caoutchouc constituents are inert, and do not influence vulcanisation.

Of the active constituents, the nitrogenous (protein) matter (the so-called insoluble constituents) is, perhaps, the most important, and in the next place, a certain part of the acetone soluble matter exclusive of resins. It was also found that the natural protein matter could be replaced by protein of other origin and also that certain basic substance, amines and even ammonia, had an accelerating effect on vulcanisation.

In the tropics, where raw rubber is produced, the latex is coagulated and treated without delay because if set aside for 24 hours, putrefaction sets in. This applies both to the latex and the wet coagulum therefrom. It was found that the rubber from such putrefying coagulum vulcanised faster than that worked up promptly. This putrified rubber, later known as "matured rubber," was found to vulcanise faster the longer it was left, up to a period of about a week, after which no advantage was obtained by allowing the putrefaction to proceed.

The rubber contains simple organic bases separable as phosphotungstates, and these accelerate vulcanisation. Knowing that some of the simple amines were accelerators, it was concluded that the matured rubber owed its activity to the putrefaction bases produced in it. Although most of the facts are in support of this explanation, there are certain aspects of the process which are not so easily explained. I have not space to deal with the matter more fully, but would point out that the action of the naturally occurring proteins (insoluble constituents) must not be confused with that of the putrefaction bases. The latter are

far more active and quite mask the effect of the former in matured rubber.

Inorganic Accelerators.

Certain inorganic substances have long been known to accelerate vulcanisation. They are divisible into two groups. The first consists of strongly basic substances, such as the caustic alkalies, lime and magnesia. The second is represented by the oxide of lead (litharge). The two last mentioned are those most frequently employed. Magnesia has come into favour, and now often replaces lime.

Magnesia and litharge have been closely studied. They differ essentially in that litharge readily reacts with sulphur to yield lead sulphide while magnesia does not. The action of both is largely dependent on the presence in the rubber of those constituents which can be extracted with acetone. This is shown by the comparative reactivities of rubber which has been acetone extracted and that which has not.

In the former, the presence of magnesia has little or no accelerating effect, but this can be restored by replacing the extract. It, therefore, appears as if the magnesia had no direct action on the rate of combination of the rubber and sulphur, but merely

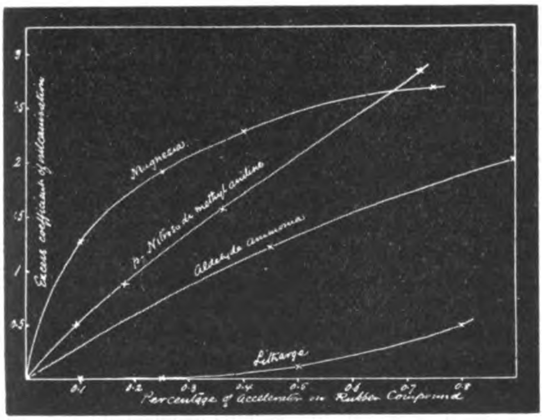

Fig 10.

acted as an activator of the acetone soluble matter, possibly by liberating the bases it contains. This view is supported by the fact that very little is gained by increasing the proportion of magnesia. One half to one per cent. is hardly less active than two or three per cent., and additions beyond this produce little or no effect. (See fig. 10.)

Litharge is much less active in small quantities as will be seen from the figure. In manufacturing practice relatively large quantities are sometimes used with advantage, and rapid vulcanisation results. There are several curious points about the action of litharge. In the first place, as it reacts with the sulphur to form a sulphide, sulphur is withdrawn from the rubber so that the rubber and litharge may be in competition for the available sulphur if the amount incorporated with the rubber is small. In spite of this, vulcanisation proceeds faster than without the litharge. When once the litharge has reacted with the sulphur it has no further influence on the course of the vulcanisation reaction, as I have found that lead sulphide itself is quite inert.

In the second place, the acetone soluble ingredient of the raw rubber is not only an essential ingredient if the litharge is to produce an accelerating effect, but if removed, the sulphur is rendered inactive or its activity is much reduced, for it is found that very little vulcanisation takes place when a mixture of acetone extracted rubber, sulphur and litharge are heated.

Litharge is an important ingredient technically, because it enables goods to be vulcanised in hot air, as, for instance, in an air oven. No oxidation takes place, as would be the case with a mixture not containing litharge. It has, however, been found that for this purpose litharge can be replaced by reducing substances such as the polyatomic phenols and oxybenzoic acids. It is also possible to vulcanise rubber compounds containing very active accelerators in the open, as the temperature is so low or the time of heating so short, that appreciable oxidation does not take place.

NOTES ON BOOKS.

Colour and Methods of Colour Reproduction. By L. C. Martin and William Gamble. London: Blackie & Sons, Ltd. 12*s*. 6*d*. net.

This book is described by the publishers as being an account of the present-day theory of colour and the methods which have been devised for the study of the phenomena of colour. It fully bears out this claim, and presents the subject in a very concise but readable form. It is divided into three parts, the first being a simple account of the theory of colour measurement and nomenclature. The second part

deals with the measurement of colour, colour vision and colour blindness, whilst the third discusses the reproduction of colour by printing and photography. It is easy to criticise any work of this comprehensive character. Chapter IV., for instance, gives a necessarily scrappy and not always accurate account of Colouring Materials. One is inclined to question whether it would not have been better to omit this hopeless attempt to compress into a few pages what is really a separate subject, and give merely the fundamental points, with a bibliography of reference to the many text books on the subject. It is only fair to the authors to add that they were evidently quite alive to the difficulty of handling this branch of the subject adequately in a single chapter.

One of the most interesting sections of the book is that in which the various instruments for measuring and recording colour are described. The theories governing the construction of "artificial daylight" appliances are very well discussed, although perhaps rather more might have been said about the various types of such lamps now available. The matter is presented altogether in a very thorough and convincing manner, and the book is a very welcome addition to the literature of the subject.

N. H.

NUX VOMICA IN MADRAS.

Although *Strychnos nux vomica*, L., the tree from which nux vomica in its commercial form is obtained is widely distributed throughout the tropical regions, the world's supply of the drug is almost entirely derived from India; two-thirds being furnished by the Madras Presidency. The important districts in which the drug is gathered and prepared are the Travancore and Cochin hills, on the Malabar coast, and the Ganjam, Godavery, and Nellore districts on the Coromandel coast.

Considering the economic value of nux vomica as the source of the alkaloids strychnine and brucine, the exploitation of the resources of India, says the United States Vice-Consul at Madras, has been greatly neglected. The trees are not cultivated, but are found in a wild state, and in general are of medium size, though occasional specimens reach 100 feet in height. At the end of the cold season in March large tufts of dull-green and white flowers appear. The fruits mature during the rains as bright-looking, brownish-yellow berries as big as a small orange, containing a gelatinous pulp in which are embedded from one to five button-shaped seeds.

The wood of the tree is hard, takes a good polish and is sometimes used for fine cabinet work. It is also reputed to have a certain value as a febrifuge. However, its economic value is not sufficient to have called forth any special protective measures, so that in places the tree has almost disappeared as the result of careless exploitation.

So far as possible the right to gather the fruits is sold by a system of licences, put up to auction annually by the forest officers of the different districts. As a matter of fact, however, owing to the difficulty of adequately supervising the work of gathering, nearly half the commercial supply comes on the market through more or less illegal channels. On account of this and the fact of its wild growth no estimates of the amount of the crop are available either before or after the season. Production is rendered still more subject to fluctuation by the price changes in foreign markets, as the domestic market is almost non-existent in an organised sense. Therefore in periods of low prices the people do not find the gathering of the crops worth while and let much of it rot in the forests.

The actual work of gathering the seeds is done by forest tribes—Gonds, Santals, Mahars—to whom this work is a secondary occupation. The pulp is washed or rotted off and the seeds are spread on mats in the sun to dry. They are then sold to small middlemen or licensees, who dispose of them to larger middlemen, and eventually the crops are consolidated in the hands of the large exporters at Madras, Cocanada, or Cochin. This method of collection is obviously more or less unsatisfactory.

The exporters wash and sort the seeds, picking out the floaters or underweight ones and the broken pieces. They are then put up in bags of 164 or 182 pounds and sold as "general average of the crop, Europe cleaning." The culls and underweights bring, as a rule, less than half the prices of the cleaned seeds, and in years of low demand may remain unsold.

The crop usually begins to arrive on the market in good quantities in December, and the gathering season extends through the cold weather up to March or April. Although the seeds can be kept for long periods, storing does not appear to be a common practice.

The most important countries of consignment are the United Kingdom and the United States. A considerable amount of the exports to Great Britain is said eventually to find its way to America.

ECONOMIC RESOURCES OF THE PHILIPPINES.

In the course of an address before the Sixth Agricultural Congress in Manila, Mr. G. L. Logan, the United States Special Agent in the Philippines, gave a summary of the economic resources of the Islands, from which the following is taken.

The Philippine Islands are largely dependent upon foreign markets as outlets for their products and, inasmuch as their economic prosperity is commensurate with this production and trade, a keen consideration of the possibilities for the expansion of both is appropriate and important at the present time, when every effort is being put forth to restore and increase that prosperity.

The most effective method for promoting trade in the islands is to develop an increased demand for the native products. The Philippines produce some articles for which there is a definite and steady demand in the markets of the world and many others which are not so well known. The commercial and industrial world should be fully informed, not only with respect to the major export items, such as abaca, sugar, copra, etc., but also regarding the many other products, now of relative insignificance, in which business of surprisingly large proportions could be developed.

With regard to coconut, there is a definite use for coir fibre and the corky substance obtained from the husk, which is now practically a waste product. Coir fibre is used in the manufacture of brushes, mats, rope, twine, fishing nets, etc., and special machinery has been devised for the purpose. Serviceable buttons and other articles can be made from the coconut shells, while coconut-shell charcoal has proved useful in the manufacture of gas masks and as a filtrant for natural gas.

There is a world demand for desiccated coconut and two or three factories have been established in the islands for its production. The increasing use of coconut oil as a substitute for animal fat and as a base in the manufacture of soap and lard and butter substitutes, adds to the possibilities of the product.

Philippine abaca is well adapted to the manufacture of brushes and brooms, and a process has been worked out for softening the fibre for use not only for sugar bags but for many woven products. Paper is being made from low-grade abaca and abaca waste, and textile chemists have produced a variety of "cotton" in conjunction with the fibre.

The Philippines produce less sugar per hectare than Java, Cuba, and other sugar-growing countries, and experiments are now being made in seed selection and fertilisation with a view to increasing the production. The vast quantities of molasses from Philippine sugar mills can be converted into alcohol for industrial uses or refined for table use. There are also possibilities for the use of bagasse, combined with asbestos, as a fireproof substitute for lumber.

The increasing interest in Philippine embroideries and hats should justify greater publicity and co-operative effort in the development of these native industries.

One of the finest pearl fisheries in the world is located in the southern waters of the Philippines, which furnishes the basis for an extensive cultured pearl industry, as well as greater development in the manufacture of pearl buttons. Enterprising initiative started, a few years ago, an entirely new industry, known as Philippine shell craft—the manufacture of household necessities in artistic and novel form.

Large sources of supply for gums and resins, which are required in several industries, are found in the islands. Rattan grows in abundance in Philippine forests, and there is a world-wide demand for hard and soft woods, which Philippine forests are well equipped to furnish. It has been proved that best-quality rubber can be produced in the Philippines and sold in competition with other rubber-producing countries.

The Philippines possess an unlimited supply of fish, suited to canning, which should be the base of a profitable industry. The fruit industry of these islands is in its infancy, although much has been done in the face of many difficulties. Lumbang nuts grow in profusion in the archipelago and the expression of oil offers no difficulties.

It is not generally known that the islands have extensive coal deposits of varying grades, some comparing favourably with coals obtained from the best known fields, while others are of lower grade, suited only for domestic consumption, for which the demand is limited.

Kapok grows wild in the Philippines, but lends itself to cultivation. A modern plant was recently established in Manila for cleaning and baling kapok. The product is ideal for mattresses and upholstery, while an edible oil is obtainable from the seed.

RICE CULTIVATION IN EGYPT.

The rice-growing area of the Egyptian Delta is confined almost entirely to the northern portions of the Provinces of Gharbia, Beheira, Sharkia, and Dakahlia in Lower Egypt, and is further restricted to those parts where the summer water supply is sufficient to allow for a short rotation, and where, owing to injurious salts in the soil, rice is required as a reclamation crop. For land reclamation it is necessary to grow rice for several years in succession, but after the land shows sufficient improvement only once in three years is required.

The marshy lands of the Nile around Rosetta and Damietta are, and have been for centuries, the chief rice-growing centres. The area sown to rice in 1893 was 115,000 acres. This steadily increased until 1904, when 219,000 acres were sown, then dropped to 202,000 acres in 1907. From that time on a steady increase has taken place, 1921 showing a total acreage of 302,000. The steady increase in the area sown, writes the United States Consul at Alexandria, is largely due to the formation of certain land companies, which have recently undertaken land reclamation on an extensive scale.

The crop is cut with small reaping hooks, and thrashing is done by native machines, except on large estates, where modern thrashers are used. Rice is hulled in small quantities by means of a stone mortar and wooden iron-shod pestle about 5 feet long, concave at the bottom. On a larger scale this work is done in various factories at Rosetta, Damietta, Alexandria, and Zagazig.

Although the quantity of rice grown in Egypt barely suffices in any season for the local demands, the country exports a large part of its crop and imports Indian and Rangoon rice

to replace it. This is due to the superiority of the quality of the rice grown locally and the high price consequently obtained for it in foreign markets.

Turkey and Greece were formerly the best overseas markets for Egyptian rice, the demand being chiefly for polished rice. More recently, however, Palestine and Syria have been by far the largest buyers.

SUBSIDISING OF INDUSTRY IN SWITZERLAND.

The Swiss Government appropriated for the year 1922 more than 50,000,000 francs for subventions to various industries in the country. The reason for this action, according to the official "Commerce Reports," (the organ of the United States Bureau of Foreign Commerce) is that the economic stability of Switzerland depends on the maintenance of certain established industries, and the Government believes that these must, at all costs, be saved from destruction during the present period of depression. It is considered more advantageous than unemployment subsidies, which are unproductive and in some ways harmful.

The industries subsidised are the following: (1) watchmaking; (2) milk production; (3) hotel operation; (4) cereal culture; (5) potato growing; (6) stock raising; and (7) the embroidery industry.

In the watchmaking industry an initial subsidy of 5,000,000 francs was granted on December 6, 1921, and an additional 6,000,000 francs on October 12, 1922. The bounty is paid only on complete watches, not exceeding 150 francs in value per piece. During the period since the establishment of the subsidies there has been a decrease in unemployment in the industry and a steadying of foreign trade, which has been attributed largely to the effect of the subsidy.

The most important subsidy, from the standpoint of cost to the Government, is that to the milk industry. It was granted to cover the losses occasioned to producers by the fixing of a price for milk and milk products below the cost of production in order to increase consumption. The total subsidies granted in 1922 amounted to 32½ million francs.

The subsidy on the production of cereals is for the purpose of encouraging the cultivation of grains in Switzerland, in order to make the country as nearly independent as possible of outside supplies. A temporary arrangement of price guarantees has been made on the wheat crop through the year 1924 to insure a margin of profit to the farmers, but it is opposed by business interests because a Government monopoly of the grain supply is involved. An endeavour is, therefore, being made to evolve a subsidy satisfactory both to the farmers and to business interests.

It is not believed, adds "Commerce Reports," that these measures will have any marked effect on Swiss-American trade unless the encouragement of cereal growing, as a result of the subsidy to that industry, should result in a diminished demand for wheat, which has been America's most valuable export to Switzerland.

VICTORIA AND ALBERT MUSEUM.

A large group of works of art, to be known as the "Alfred Williams Hearn" gift, has been presented to the nation by Mrs. A. W. Hearn. It forms the first instalment of a collection made by her late husband and augmented by herself and has been placed on exhibition in Room 105.

The goldsmiths' work includes two pieces of considerable size, a Spanish monstrance in silver-gilt decorated with enamelled bosses, dating from the early part of the 17th century; and an altar-cross of rock crystal and silver-gilt, Naples work of the latter part of the 15th century. Among the English silver is a good example of the Elizabethan Communion cup, dated 1575; a tiger-ware jug with finely worked silver-gilt mounts of the 16th century; and a bowl of mother-o'-pearl with silver mounts and handles, an attractive specimen of the Charles II. period. There are several pieces of Augsburg and Nuremberg work in silver-gilt of the 17th century, and an important group of Spanish jewels with paintings under crystal. The bronzes include the head of a crosier, boldly worked with foliage and inscribed with the name of Giovanni Ricci, Archbishop of Pisa (d. 1574); an English sanctus bell dated 1310, with its iron-mounted beam; and a fine bronze measure inscribed "Elizabeth Regina 1601." The collection includes some interesting examples of decorative wood and leather work. A German cabinet, in ivory, with painted metal plaques, ascribed to the latter part of the 16th century, is also of importance; and a small, but interesting, series of Japanese lacquer may also be mentioned. Among the examples of sculpture may be noted an interesting oak figure of St. Michael, probably English work of the early 15th century; a bronze cast of the figure of Peter Vischer (1455-1529) from that artist's elaborate shrine of St. Sebald at Nuremberg; and a large collection of ivory carvings.

The pottery includes two Spanish (Valencia) drug-pots of the 15th century, painted in blue and copper lustre. There are several examples of Italian earthenware of the 17th and 18th centuries, a pilgrim's bottle of unglazed earthenware from Salzburg, and a Delft polychrome plate of

an uncommon type. Among the glass is a plaque representing the Adoration of the Shepherds; it is signed P.C.F. and is Italian work of the 16th century. Another object may be mentioned: a curious glass casket with numerous panels engraved with harbour scenes — probably Italian work of the 17th century. A portrait of Frederick, second Earl of Guilford, by John Downman, A.R.A., signed and dated 1780, is an excellent example of the artist's small water-colour portraits.

FRENCH PRODUCTION OF CREAM OF TARTAR.

The wine districts of Southern and South-Western France and Algeria are the largest sources of supply of cream of tartar in the world. It is estimated that Southern France and North Africa produce on an average 10,000 tons of argols per annum. Argols are the crystals which form on the sides of wine casks, the precipitation being about 1 millimetre (less than four one-hundredths of an inch) per annum. These crystals contain 75 per cent. of cream of tartar. Sometimes the scraping of the casks is deferred until two or three years' precipitation has accumulated. In years when the price of wine is low the growers scrape their casks in order to supplement their income by the sale of the argols, and accordingly in such years as much as 12,000 tons of argols may be offered; in years when the price of wine is such that growers do not feel the need of funds, they are apt to leave their casks unscraped and the offering of argols may be as low as 8,000 tons. The higher the alcoholic content of wine the lower is the precipitation of argols; so that the ordinary red wines with nine degrees of alcohol give more tartar than the high-grade wines with 12 to 20 degrees of alcohol.

Of the average figure of 10,000 tons it is estimated that some 4,000 tons find their way to two large American firms whose importing headquarters are at New York City. Of the remaining 6,000 tons some 1,200 go to independent buyers in the United States, 2,000 tons come to England, 2,000 tons are used in France, and 800 tons go to Germany. Many of the largest American baking-powder companies do not buy cream of tartar, as they manufacture alum powders. Even the oldest American baking-powder companies are now adding tartaric acid to their formulas to replace a part of the cream of tartar formerly used. The English baking-powder companies employ a higher proportion of tartaric acid than has been used in the United States until recently.

According to a report by the United States Consul at Marseilles, France has 18 cream of tartar factories, located chiefly in Marseilles, Montpellier, Beziers, Aubais, St. Thibéry, and Bordeaux. Prior to the war these factories exported something like 6,000 tons of cream of tartar per annum, but this figure has now shrunk to approximately 2,000 tons. The sales are made largely in Australia, Canada, England, and Japan.

In addition to the argol production there are available in the South of France and Algeria each year some 15,000 tons of wine lees taken from the bottom of wine casks, containing from 18 to 20 per cent. of cream of tartar. About 3,000 tons of these have been worked up in France, but an additional 4,000 tons are now to be used in a factory which has just been erected at Montpellier. About 2,000 tons of wine lees are also exported to Germany and the remainder discarded.

GENERAL NOTES.

Production of Venice Turpentine.—The production of Venice turpentine (trementina) in Italy is confined to the Province of Venetia Tridentine, formerly Austrian Tyrol territory, in the northern part of Italy. In this region that species of pine known as larch is found in abundance on the slopes of the Apennines, and the distillation of turpentine from the wood of this tree forms an important industry. There seems to be no monopoly of the industry, as, according to the United States Vice-Consul at Venice, the production of Venice turpentine (known to the producers as olio greggio di larice or Tyrol larch turpentine) is divided among a great number of individuals and small concerns. In some cases the municipal government owns and operates distillation plants for the production of turpentine—an unusual occurrence in Italy. Venice or Tyrol larch turpentine is sold by weight.

Fusel Oil Production in Czechoslovakia.—Fusel oil is a strong-smelling oil produced along with alcohol during the fermentation of grain, potatoes, etc., on a large scale. The annual output of fusel oil in Czechoslovakia approximates 150 metric tons, 95 per cent. of which is exported. Germany is the greatest purchaser of Czechoslovak fusel oil, followed by the United States, Holland, Austria, Hungary and Switzerland. After it was discovered that fusel oil could be used in certain chemical processes, and the demand increased, all spirit refineries in Austria-Hungary joined together and delivered their output of fusel oil to the largest refineries in Bohemia. The Czech refiner was thus able to control the entire business. According to a report by the United States Consul at Prague, this old system is still in force, and all the succession States of Austria-Hungary are now concentrating their output through this firm in Czechoslovakia. Of the total amount of fusel oil produced in Czechoslovakia, only five per cent. is needed to supply the local demand, due to the fact that industries using this oil are still in their infancy.

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PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

THE VULCANISATION OF RUBBER.

By Henry P. Stevens, M.A., Ph.D., F.I.C.

Lecture III.—*Delivered February 19th*, 1923

Organic Accelerators.

I have shown that the vulcanisation of raw rubber is dependent on the presence in the rubber of certain accessory bodies usually referred to as natural accelerators. Synthetic rubber would, therefore, be difficult to vulcanise without the addition of some catalyst or vulcanisation accelerator to take the place of the substances which are found associated with Para rubber in the natural state. The fact that the naturally occurring nitrogenous (protein) constituents could be replaced by other forms of protein led to experiments in which protein or similar nitrogenous matter was added to synthetic rubber in process of manufacture. Later various other nitrogenous substances were tried, and among these the nitrogenous organic bases which were found to accelerate the rate of combination of natural rubber and sulphur.

Early experiments indicated that the weaker bases were not efficient accelerators. The Baeyer interests actually obtained patents to cover the use of all organic bases as accelerators having over a certain dissociation constant. According to Spence, he and his colleagues were using these organic bases antecedent to the German patent application. In the *Kolloid Zeitschrift* will be found a paper by Spence, dated August, 1913, giving the vulcanisation curves of a number of rubber specimens compounded with sulphur and a substance marked P-D. With increasing proportions of P-D from nil to five per cent., progressive increase in the rate of vulcanisation is shown.

I must confess that when this paper first appeared, I was much puzzled by the letters P-D, and suspected that P must refer to protein, P-D representing protein modified in some manner. Looking back to-day, I do not think I should be far wrong in spelling P-D piperidene.

The discovery of the accelerating effect of organic bases led to the adoption experimentally of several of the more easily procurable ones, such as aniline, hexamethylene tetramine and aldehyde ammonia. The two latter are powerful accelerators, but aniline has little or no accelerating action, and has now been generally discarded. At one time, it is said to have been used in America on a considerable scale. Hexamethylene tetramine or hexamine, sometimes abbreviated to H.M.T., is a non-volatile odourless substance, and, therefore, convenient for use on a large scale, and is, I believe, very popular still. Aniline and aldehyde ammonia are volatile, have unpleasant odours and the former is toxic. The same disadvantages attach to a number of the stronger bases, such as the piperidene already mentioned.

To overcome this difficulty, it was sought to prepare stable, non-volatile and odourless derivatives which would retain the accelerating effect of the original base. For this purpose use has been made of the carbon disulphide addition products; thus, in the case of aniline a substitute was found in thiocarbanilide. It was, however, soon discovered that these addition products owed their activity to something more than the mere fact that they were derivatives of the active bases, for in many, if not all, cases, the carbon disulphide addition product, when used in conjunction with zinc oxide, was found to be more active than the base from which it was prepared. This thiocarbanilide, although approximately only

one-third as active as hexamine, is yet more active than aniline, and serves as a useful accelerator on a manufacturing scale.

It, therefore, appears that the basic nitrogenous substances do not necessarily owe their efficiency to their activity as bases, although, as a general rule, the powerful bases, such as piperidene, dialkylamines and similar substances were found to be more active than weaker bases. This applies both to the bases themselves and to the compounds produced by reaction with carbon disulphide and in the presence of zinc oxide.

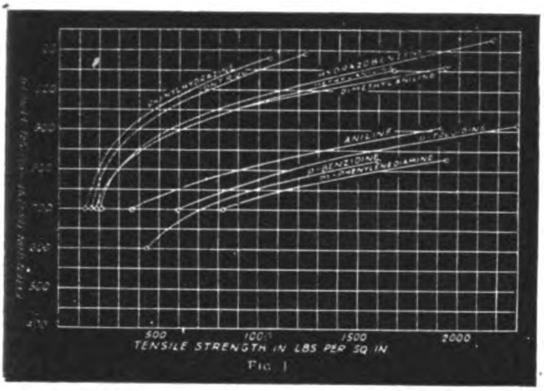


FIG. 11.

This class of substances is sometimes termed carbo-sulphydril accelerators, from the constitution of the molecule.

About this time Peachey discovered that p-nitroso-dimethylaniline was a powerful accelerator, and some other nitroso compounds, such as nitroso-naphthol share this property. These nitroso derivatives are acidic rather than basic in nature, and, to explain their efficiency, it would be necessary to assume that during vulcanisation the nitroso group is reduced to an amino group. This, however, will hardly suffice to explain why phenylhydrazine, a well marked basic substance, does not accelerate, but actually retards, vulcanisation. Kratz and his co-workers have compared the activity of a number of bases with their dissociation constants.

The load stretch curves obtained are shown in fig. 11. To interpret these it will be noted that the higher the position of the curve on the chart the greater the extension and the lower the tensile strength. The curve for phenyl hydrazine with a dissociation constant of $1 \cdot 60 \times 10^{-9}$ lies above that for the control, so that this strong basic substance has a retarding effect. Metaphenylene diamene, with the lowest dissociation constant ($1 \cdot 35 \times 10^{-12}$) of any of the substances chosen, gives a curve taking the lowest position of any, that is, it is the most efficient of the substances tried. There is, therefore, no relationship between the basicity and efficiency of an accelerator of this type. Then, again, the carbon disulphide addition products with the alcohols, that is the xanthates, are powerful accelerators, and these contain no nitrogen. The alcohols from which they are produced are certainly not basic substances. On the contrary, they form salts by replacement of hydrogen by metals. Also, the carbon disulphide addition product of phenalhydrazine has been examined in my laboratory and found to be a powerful accelerator.

Some groups of sulphur derivatives which act as accelerators are of special interest as they split off active sulphur so readily that they vulcanise rubber without the addition of any elemental sulphur. I have indicated that the efficiency of carbon disulphide, or similar sulphur containing accelerators of the carbo-sulphydril type, is found to depend on the presence of basic mineral ingredients, particularly zinc oxide. This led to experiments in the use of the zinc salts of some of these derivatives. Thiocarbanilide does not form a zinc salt, as it does not contain the SH or OH group. The condensation products of piperidene, diethylamine, alcohols and other substances which have a different constitution yield zinc-containing products. Bruni claims that these zinc salts are more active accelerators than the original substances from which they were obtained, but this view is not shared by Twiss. In any case, zinc oxide is necessary to bring out the activity of the accelerator to the full whether the original substance or its zinc salt be used.

Other metallic salts, such as those of magnesium, cadmium and lead have been tried, but the general experience indicates that the zinc salts are the most active of the metallic salts, and that zinc oxide is the best activator. I have tried zinc sulphide, but this is inactive. As zinc oxide is a well-known compounding ingredient extensively used by rubber manufacturers, it is a fortunate coincidence that

this substance and not the oxide of some less available metal possesses the desirable activating property to such a high degree.

Some of the ordinary compounding ingredients have the reverse effect, that is to say, they counteract the effect of the accelerator. To this group belong the metallic sulphides, and, in some instances, such common ingredients of rubber mixings as magnesia and its carbonate and bases, including the alkalies and alkaline earths. Small quantities of the golden sulphide of antimony completely neutralise the effect of the carbo-sulphydril type of accelerator. Each accelerator requires to be examined individually to ascertain what ingredients are harmful and detract from its efficiency. It is curious that in some cases caustic alkalies should negative the effect of the acclerator as either caustic soda or potash by itself acts as an accelerator. As, however, either of them would decompose the zinc salts forming the corresponding sodium or potassium salts, which are much less active, we have a rational explanation in this instance.

It is convenient to consider the organic accelerators in two groups, (1) the mild and moderately active substances, and (2) the very active or so-called ultra-accelerators. This division does not necessarily relate to the chemical composition of the accelerators or to their mode of action, of which we know very little. It is more convenient to consider them from the point of view of their activity, as the effect produced by the very active accelerators differs markedly from the less active and the latter only function in the presence of zinc oxide. It is noteworthy that these ultra-accelerators will produce satisfactory vulcanisation from a technical standpoint at low temperatures.

The number of the less or moderately active accelerators in use is small. Most of the important ones have been referred to. I might mention the di-and tri-phenyl guanidine and the compound of aniline and formaldehyde. Of the very active accelerators I have already cited, the carbon disulphide addition products of piperidene, diethylamine and the alcohols (xanthates), but mention may also be made of the more recently discovered dithio acids and the mercaptothiazoles. A short description of these will now be given. When carbon disulphide reacts with dialkylamines, three substances are formed (Maximoff). The formulæ are as follows (R represents an alkyl group):—

(1) $R_2N-C(=S)SH. \quad NHR_2.$
Dialkylamine dialkyl dithiocarbamate.

(2) $R_2N-C(=S)-S-S-C(=S). \quad NR_2.$
A thiurame disulphide.

(3) $R_2N-C(=S)-NR_2.$
Tetraalkyl thiourea.

When (2) is warmed with an alcoholic solution of KCN a monosulphide is obtained.

(4) $RN_2-C(=S)-S-C(=S)-NR_2.$

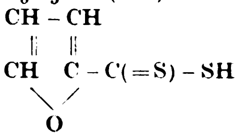
Of these substances (1), (2) and (4) are ultra-accelerators while (3) is inactive.

(2) is obtainable from (1) by oxidation with a halogen. Both (1) and (2) give white zinc salts. $R_2N-C(=S)-S-Zn-S-C(=S)-NR_2$. This latter is presumably the active substance.

The xanthates resemble the thiurames in constitution, the N_2R, group being replaced by the OR group. Thus the formula of the zinc salt becomes $OR-C(=S)-S-Zn-S-C(=S)-OR$.

The dithio acids are substances obtained by the action of hydrogen persulphide on the aldehyde, e.g.,

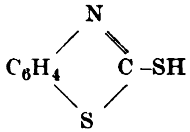
$C_6H_5.\ C(=S)-SH$ dithiobenzoic acid and



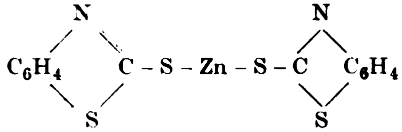
dithiopyromucic acid.

Here again it is the zinc salts which constitute the active accelerators.

The mercapto thiazoles have the following constitution, which may be illustrated by the benzene derivatives.

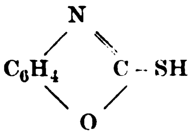


and the zinc salt presumably

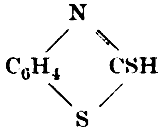


All these bodies are, therefore, of the disulphide type, and it has been suggested that one of the central sulphur atoms is split off to yield the monosulphide. However, according to Maximoff, the latter (see formula (4) above) is also an ultra accelerator. It should, therefore, have the power of recombining with sulphur at low temperatures to reform the disulphide. Sebrell and Boord have studied the analogues

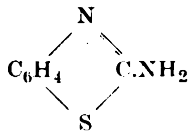
of mercapto-benzothiazole to ascertain how far the thiazole nucleus affects the activity of the accelerator. Thus, it has been found that the effect of replacing the SH group by the OH group is greater than of replacing the ring sulphur by oxygen. Mercapto-benzooxazole



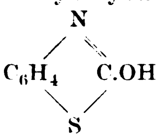
is less active than mercaptobenzothiazole



but the oxazole is more active than the amino-

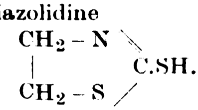
benzothiazole 

Also the hydoxybenzothiazole

 is much less active

than the mercaptobenzothiazole.

Mercaptothiazolidine



although an efficient accelerator is also less active than the mercaptobenzothiazole.

Homologues of the latter have been prepared, the variously placed hydrogen-atoms of the benzene ring being replaced by methyl groups. There is little difference between the monomethyl derivatives, but the dimethyl derivatives are more active. On the other hand, the methoxy and ethoxy derivatives are much less active. There is much scope for research on these lines, and a study of the reactivity of the accelerator resulting from alterations in the configuration and constituent groups of the accelerator molecule should lead to a better understanding of the nature of the essential reaction involved.

The accurate study of the action of a single accelerator is a long and tedious business. A rough test can be made by taking a base mix which should contain a fair percentage of zinc oxide, and incorporating with it a small known percentage of the accelerator. Some accelerators appear to be exceptionally active at low temperatures, as, for instance, the xanthates and, for comparative purposes, a range of specimens vulcanised at various temperatures should be made. For accurate study, test samples cured for progressive periods must be vulcanised, rings cut and the load stretch curves measured.

This routine has been carried out by Twiss with a number of accelerators, and the following data are taken from his papers. All experiments were made with a base mixing of rubber-sulphur 9/1. The proportion of sulphur is larger than would be used in practice, and his results do not illustrate the remarkable effect obtainable with much smaller proportions of sulphur to which I shall refer later (some figures with smaller proportions of sulphur have

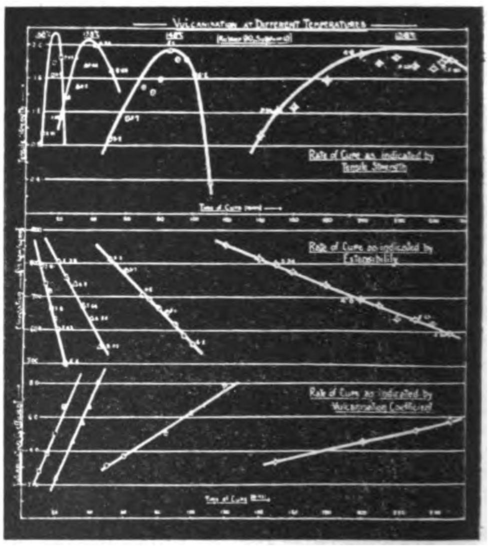


Fig. 12.

been recently published by Schidrowitz and Bean). This should be borne in mind when interpreting the figures.

The first experiments were made with the above base mix to which were added thio-carbanilide and hexamine for varying periods of vulcanisation. In each case the curves were traced for (1) breaking strain (2), elongation at a given load (50 kg. per sq. cm.), and (3), the coefficient of vulcanisation. I reproduce some typical curves (figs. 12 and 13). It will be noticed that the addition of the above-mentioned accelerators does

not alter the general character of the curves as yielded by the base mix alone (fig. 12).

If you will recall to mind the curves illustrated in the first lecture, you will remember that there was a close concordance between the elongation at a given load, the coefficient of vulcanisation and the time of cure. The latter, as far as could be ascertained, were directly proportional to one another, but the elongation showed some variation. With smoked sheet, the curve was almost rectilinear, but with crepe a distinct curvature was apparent.

This curvature varies with different specimens and with the method of vulcanisation. The former curves were obtained by treatment in open steam, whereas Twiss employed moulds for his specimens. I am inclined to think this difference in procedure is of importance, as I have noted appreciable differences in the efficiency of the same accelerator according to whether the specimen was open cured (wrapped in cloth) or mould cured in a press. It will be seen that the relationship of elongation to time of cure as represented is rectilinear.

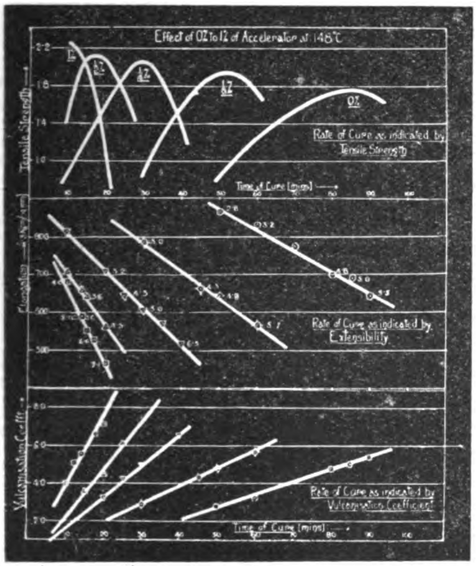


FIG. 13.

Fig. 13 refers to aldehyde ammonia as a catalyst. I am of opinion that the relationship shown in this figure is not perfectly represented by the straight lines as drawn. However this may be, there is a marked increase in curvature when we pass from the unaided accelerator to one used in conjunction with zinc oxide. This applies to a standard rubber sulphur mix with which as little as one per cent. of zinc oxide has been incorporated, and is clearly seen in fig. 15, which relates to four specimens (1) the rubber sulphur standard, (2) the same containing ½ per cent. H.M.T., (3) resembling (1) but containing in addition, one per cent. of zinc oxide, and (4) resembling (2) with a similar addition of zinc oxide.

The lower part of the diagram gives the relationship for elongation and time of cure. Whereas this is rectilinear for 1 and 2, it is markedly curvilinear for 3 and 4. The same applies to the relationship of the coefficient with the time of cure (not shown in the figure).

There are two other characteristics of these zinc oxide acclerator compounded rubber samples deserving of mention. First the maximal tensile strength is reached

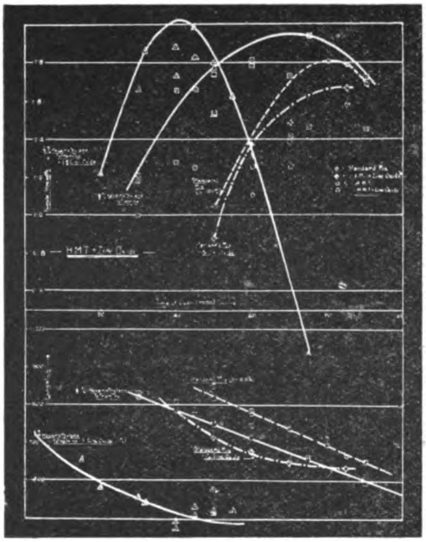


FIG. 14.

at a lower elongation and with a lower coefficient than in the case of the unaided mixing, and secondly, the value of the maximal tensile strength is greater, so that, as a result, the rubber not only vulcanises faster, but its tensile properties improve more quickly and reach a higher maximum. This may be seen by comparison between the two continuous curves in the upper part of fig. 14. That corresponding to the mix containing zinc oxide and accelerator lies to the left of that without zinc oxide and gives a higher maximum.

Zinc oxide without an accelerator produces a stiffening effect, and reduction of elongation at a given cure, as do all finely divided pigments, but the effect produced is small, and is not comparable with the combined effect of zinc oxide and accelerator. This is shown by the two dotted curves in the upper part of fig. 14, which correspond to the standard mix with and without zinc oxide. It will be noted that the curves lie close together and are not differentiated as the corresponding curves for the accelerrated mixings.

If the proportion of the accelerator to zinc oxide be increased, the curves show peculiar irregularities. Fig. 15 is a repeat of a previous figure with the same amount of zinc oxide, but double the amount of accelerator

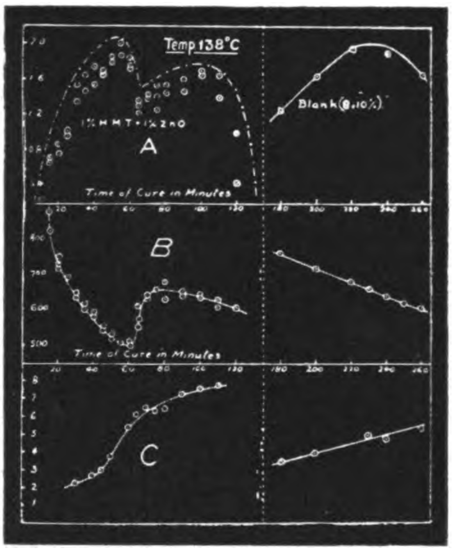


FIG. 15.

(HMT). Both the tensile and elongation curves show a double inflection within a short interval. That is, the tensile strength increases and the elongation is reduced during the first hour of the cure, rising to a coefficient between 5 and 6. On longer heating, the tensile strength falls and the elongation increases, both changes taking place rapidly.

The final stage is a gradual increase of tensile strength and decrease of elongation as in the earlier part of the cure. It is noteworthy that the coefficient, although giving an S-shaped curve, does not show irregularities to the same extent as the elongation and tensile figures. That is, although the rate of combination of the rubber and sulphur is in places decelerated, yet in no instance is sulphur split off from the rubber causing a decrease in the coefficient.

This inflection of the curve at the middle period differs from the "reversion" as discussed in a previous lecture in that the change is not continuous, but takes place suddenly. Moreover, it is followed by a resumption of the normal process. The

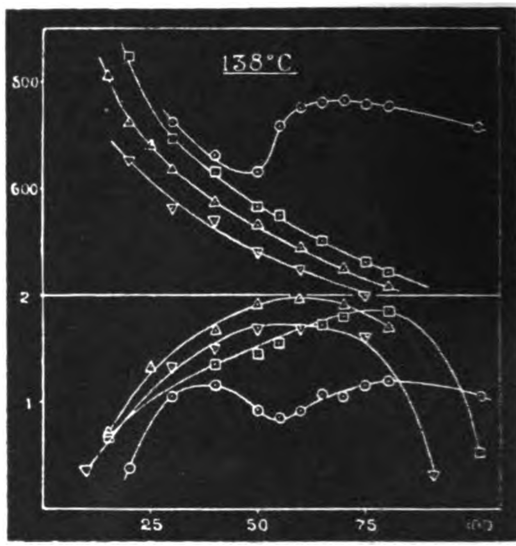


FIG. 16.

results indicate some change in the chemical reaction taking place as shown by the curve for the coefficient. Twiss suggests the formation of decelerating products, the function of the zinc oxide being to neutralise or remove these from the sphere of action as fast as they are formed. This view is supported by the fact that these irregularities in the vulcanisation curves do not occur in the presence of a sufficient excess of zinc oxide, and that the larger the proportion of zinc oxide employed, the more efficient the accelerator.

The effect of varying the proportion of zinc oxide is shown in fig. 16, which gives the elongation with the same accelerator as before (HMT), but with different amounts of zinc oxide, that is, ½, 2 and 5 per cent. With both tensile and elongation figures the ½ per cent. zinc oxide gives the characteristic bent curves, but with larger pro-

portions these assume a regular shape. Fig. 17 shows the effect of varying the proportion of the accelerator, keeping the proportion of zinc oxide constant. With 1 per cent. and 2·5 per cent. of HMT, the curve is bent, but with ½ per cent. it takes a normal course.

Although considerable acceleration of vulcanisation is obtained with HMT and other accelerators of this type, in the

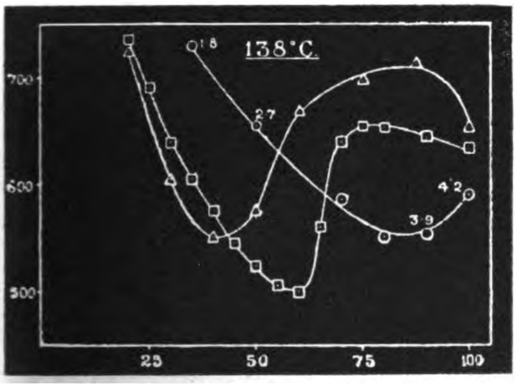


FIG. 17.

presence of zinc oxide, the results are not of the same order as those obtainable with the ultra-accelerators of which the chemical constitution has been given. Fig. 18 illustrates the course of the curves obtained with the condensation product of piperidene and carbon disulphide. The amount used is only one-quarter per cent. on the rubber, and the three curves show the effect of this accelerator (1) alone, (2) with 1 per cent. of zinc oxide, and (3) with 5 per cent. of zinc oxide. Taken alone, the acceleration produced is of a mild character, maximal tensile strength being obtained in about 200 min., but with 1 per cent. zinc oxide, this period is reduced to about 50 min., and with 5 per cent. of zinc oxide the maximal effect is over-stepped with the first observation made. With this and similar accelerators, vulcanisation can be carried out in periods as short as 5 or 10 min., and provided time be given, at temperatures such as 100 deg. Cent., and lower.

In the first lecture I drew attention to the temperature coefficient of the vulcanisation reaction, that is, the temperature coefficient determining the rate of combination of rubber and sulphur. Spence obtained a figure of 2·65, and other investigators have published figures of a similar order. Thus, Twiss gives the figure of 2·3 as the average of a number of determinations with rubber and sulphur in the proportion 9/1. Twiss has also published data which enable a determination to be made of the temperature coefficient in the presence of accelerators, and it is interesting to note that the figures obtained are almost identical with those given by unaccelerated mixing.

Thus, with aldehyde ammonia figures of 2·3 and 2·4 were obtained. In other words, a rise of 10 deg. Cent. in temperature produces the same percentage increase in rate of combination whether in the presence or absence of an accelerator such as aldehyde ammonia. Similar figures are obtained if the rate of vulcanisation be based on the

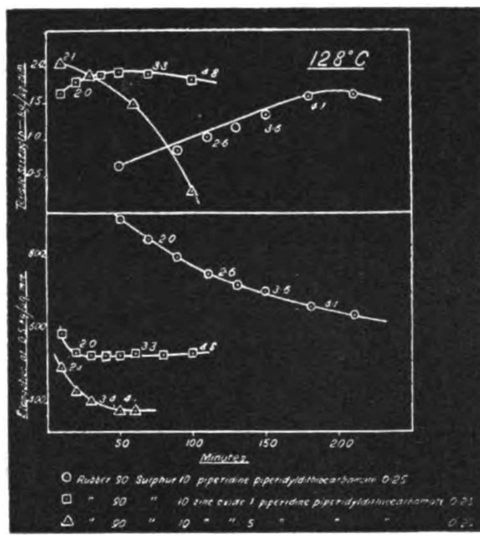


FIG. 18.

elongation at the maximal breaking strain, that is to say, on the physical properties of the vulcanised rubber. This results from the approximate rectilinear character of the vulcanisation curves.

An approximate comparison of the accelerating power of different substances may be made by reference to the "acceleration factor." This gives the ratio of the time required to fully vulcanise the rubber and the time required to produce the same degree of vulcanisation in the same mix in the presence of one per cent. of the accelerator. It remains to fix the property

on which the degree of vulcanisation is to be based. I have already pointed out that the addition of an accelerator not only reduces the time or temperature required to produce a given physical state or percentage of combined sulphur, but also reduces the elongation when the tensile figure is at a maximum. The following figures will give some idea of the effects produced :—

Rubber-sulphur 9/1 mix	Elongation at maximal tensile strength. Load 50 kilos per sq. cm.	Coefficient at maximal tensile strength.
Unaccelerated mix ..	680 700	.. 5 to 5.5
Accelerated without zinc oxide . ..	650 680	.. 4.5 to 5
Accelerated conjointly with zinc oxide	350 500	.. 1 to 2.5

As a consequence it follows that the state of cure as given by the maximal tensile strength will be obtained with a different elongation and a different coefficient, according to the activity of the accelerator. For this reason, the maximal tensile strength is, perhaps, the best figure to take when comparing the efficiency of different accelerators. On this basis the accelerator factor may vary from almost nil to a figure of 7 or 8 for the most active accelerators in the absence of zinc oxide. In the presence of zinc oxide the factor may considerably exceed 100, that is to say, the rubber will vulcanise more than one hundred times as fast as the unaccelerated mixing. It is, however, usual to reduce the amount of sulphur so that the effect is not so marked in practice.

Accelerators are sometimes referred to as vulcanisation catalysts, but there is some doubt whether they should be regarded as true catalysts. We have seen that very small proportions influence the rate of vulcanisation, and as far as we know, the final product, considered as a caoutchouc sulphide, is the same whether the accelerator be present or not. On the other hand, the physical properties of a vulcanisate containing a definite amount of the caoutchouc sulphide varies according to whether the product was obtained with or without an accelerator. Moreover, a catalyst should remain unaltered at the end of the reaction, but it has not so far been found possible to extract the original accelerator from the rubber after vulcanisation. There is no doubt considerable experimental difficulty in carrying out such an operation, but there seems to be good grounds for believing that the accelerator itself undergoes some change or decomposition in the process of vulcanisation.

Theory of Vulcanisation.

Of recent years increasing attention has been given to the colloidal state of matter of which rubber is a typical member, and several distinguished chemists have devoted their whole energies to particular branches of the subject. Unfortunately, the class of colloid to which rubber belongs happens to be one of the most difficult of investigation and the type about which least is known. Consequently we cannot look for much help from the study of other and analogous colloids such as gelatine. In fact, some chemists have become so imbued with the physical aspects of the so-called chemistry of colloids that they will hardly admit the existence of chemical reactions unless these result in some very radical and sudden change in the properties of the product formed.

Thus, raw rubber is admittedly an unsaturated hydro-carbon and consequently combines with more or less ease with other substances. For instance, it can take up ozone to yield ozonides; chlorine, bromine and iodine to yield the corresponding chlorides, bromides and iodides. It also combines with the halogen hydrides, the nitrogen oxides, etc. All these products are admittedly the result of chemical reactions. The process is carried to completion by the use of an excess of the reagent, and the resulting products are sharply distinguished from the original raw rubber.

If we heat raw rubber with an excess of sulphur until it has combined with the maximal amount we obtain a product—ebonite or hard rubber—totally dissimilar from the original raw material, or if we treat raw rubber dissolved in a suitable medium with an excess of sulphur chloride we obtain a similar hard black product quite different in appearance and properties from the original material. Yet there are distinguished chemists who deny that any chemical reaction has taken place. The change in physical properties is, we are assured, brought about by the adsorption of sulphur or sulphur chloride as the case may be. Wolfgang Ostwald, the protagonist of the adsorption theory, set out the reasons in favour of his views against the chemical

interpretation. I will take the points in order giving the reasons for dissent from the conclusions drawn.

(1) *In all specimens of vulcanised rubber whatever proportion of sulphur be used, there always remains a residue of "free" or uncombined sulphur. If vulcanisation be an addition reaction, one would expect the whole of the sulphur to enter into combination under favourable circumstances.*

Spence found that there is a definite limit to the amount of sulphur which can be taken up by the rubber. The figure is approximately 32 per cent to 33 per cent. and corresponds to the formula $C_{10}H_{16}S_2$. As sulphur reacts with the protein and resinous constituents of raw rubber the exact maximal percentage of sulphur combined with the rubber (hydrocarbon) is difficult to fix with certainty, but the figure is so close to that required by theory that the matter appeared to be disposed of.

Spence's experimental results have been criticised. It has been stated that he did not work with a sufficiently large excess of sulphur. He used two or three per cent. more than actually entered into combination with the rubber, and recent work indicates the possibility of more highly sulphurised products. Thus, van Heurn obtained 37 per cent. of combined sulphur calculated on the rubber by heating a mixture of equal parts of rubber and sulphur for six hours at 35½lb. steam pressure, and Skellon obtained still higher figures- up to 50 per cent. (see fig. 21.). I consider, however, that the possibility of degradation and decomposition of the rubber must be taken into account, as the completion of the reaction necessitates long heating at relatively high temperatures. An observation of Skellon that he could extract more free sulphur from his vulcanisates by using acetone under pressure, that is at higher temperatures, is very significant of the condition of his vulcanisates. Knowing as we do that ebonite or vulcanite (hard rubber) as ordinarily prepared is an extremely inert material and resistant to corrosive chemicals, it seems unlikely that it would be decomposed to yield free sulphur by merely raising the temperature of the acetone used for extraction.

The work I carried out on vulcanised gels opened my eyes to the unstable character of vulcanised rubber on prolonged heating. The degradation or decomposition proceeds with increasing solubility in raw rubber solvents such as benzene, while the rubber still retains the physical character associated with the material. The degradation or decomposition may proceed to a stage when the vulcanisate becomes largely acetone soluble. In my opinion, there is little doubt that the highly sulphurised products of van Heurn and Skellon consist to a large extent of rubber and sulphur compounds of simpler character and possibly of different percentual composition from those sulphides present in normally vulcanised rubber.

The experimental difficulties met with in these investigations may also result in false conclusions, and, although I consider that the degradation or decomposition of the caoutchouc molecule is mainly responsible for the results obtained by Skellon, it is also as well to remember that the extraction of the last few per cent. of free sulphur from the vulcanite is a very tedious process owing to the insolubility of acetone in the rubber. The amount extracted in any given time interval steadily decreases, and it is difficult to know when the extraction is really complete.

These extracts are assumed to consist of sulphur with small quantities of some of the non-caoutchouc ingredients naturally present in the raw rubber used. As, however, degraded products obtained by heating vulcanised rubber are partly acetone soluble, it is possible that part of the extract which has been assumed to consist of free sulphur is actually composed of degraded compounds of rubber and sulphur. This degradation or decomposition may be of the character of an oxidation, and extraction experiments should be carried out as far as possible in the absence of air. There is no doubt that once the natural acetone soluble constituent is removed from rubber the product readily oxidises and resinifies even in the cold, and whether vulcanised or not. Just as rubber combines with sulphur it similarly combines with sulphur chloride yielding an addition product which was exhaustively investigated by Hinrichsen and Kindscher. A substance was obtained of the formula $(C_{10}H_{16})_2\ S_2Cl_2$. When vulcanised rubber is brominated, the sulphur is retained by the caoutchouc, whereas had the sulphur been mechanically absorbed, a bromide would have been obtained free from sulphur. Spence showed that not only does the bromide contain sulphur, but that it contains less bromine than is yielded by raw rubber $C_{10}H_{16}Br_2$, part of the bromine being replaced by an

equivalent of sulphur, that is, $Br_2 = S$. These results have not been confirmed. There is no doubt that the chlorinated, brominated, etc., products of vulcanised rubber still retain a part of the sulphur combined in the vulcanising process, but there is some doubt as to the proof of the equivalency. Van Rossem, repeating Spence's work, was unable to confirm the equivalency.

(2) *When vulcanised rubber is extracted with solvents for sulphur, small quantities of sulphur can be extracted by progressive treatment. Unvulcanised mixtures of rubber and sulphur behave in a similar manner.*

The difficulty of removing the last traces of free sulphur from a vulcanised rubber is exactly what would be expected if the free sulphur were mechanically held. The solvents available, such as acetone, are not the most effective solvents for sulphur. They are used because they have no solvent action on raw or vulcanised rubber. Consequently, the extraction of sulphur is a very slow process and the last traces are removed with great difficulty. The same has been shown to be the case with unvulcanised mixtures, but the amount remaining unextracted is then negligible.

Recent experiments have shown that, contrary to Ostwald's statement, prolonged extraction does eventually remove the whole of the free sulphur from a carefully prepared vulcanisate. Sulphur exists in a variety of allotropic modifications, some of which are more insoluble than others. At the temperature of boiling acetone, these will be gradually converted into the more soluble modifications, but the process is a slow one. It is known to be impossible to remove the last trace of sulphur from an unvulcanised mixture. This, however, may be due to a very slight combination of rubber and sulphur brought about by the mixing on hot rollers and the prolonged heating in the process of extraction.

Finally, it should be remembered that vulcanised rubber is not a perfectly stable substance, and the removal of the acetone soluble constituents renders it very susceptible to auto-oxidation with subsequent decomposition, and if traces of sulphur are removed after prolonged extraction this may be due to the removal of soluble decomposition products containing sulphur. I have shown that when vulcanised rubber is highly degraded, the greater part becomes acetone soluble. This may help to explain the results more recently obtained by Harries and Fonrobert. The vulcanised rubber, which was said to be of normal properties was extracted on a relatively large scale for laboratory experiment. The residue after 60 days' extraction was found to contain only 0.29 per cent. of sulphur. It appears as if the whole of the sulphur would have been removed if the extraction had been continued long enough. The vulcanised rubber was evidently undercured and degraded, as it sunk together during extraction. It does not seem as if much effective extraction took place during a part of the time, and no doubt oxidation set in between the heating periods.

Whatever the reason, I determined to check these results by independent tests of my own and carried out in such a manner as to avoid the weak points of Harries' experimental procedure. My samples were vulcanised under the same conditions of time and temperature as those of Harries, but were in the form of a thin sheet which could be effectively extracted. I noticed no softening or sinking together of the material during extraction, and a number of careful analyses showed that during the first week the whole of the free sulphur was extracted, giving a figure for the combined sulphur of 1·54 per cent. At the end of the second, fourth and ninth weeks the figures obtained were 1·54, 1·47 and 1·55 respectively, so that instead of a dwindling proportion of combined sulphur the amount remained constant and unaffected by further extraction.

A parallel test with a less vulcanised rubber (combined sulphur 0·95) gave exactly similar results. The matter is of great theoretical interest, for if there be no chemical bond between rubber and sulphur in vulcanised rubber, it should be possible to prepare a vulcanisate having the characteristic properties of vulcanised rubber after the removal of the whole of the sulphur. Harries' extracted product could not be described as a typical vulcanised rubber, and my experiments show that the characteristics of vulcanised rubber cannot be dissociated from a proportion of acetone insoluble (or combined) sulphur.

When referring to recent work with ultra-accelerators, it was shown that the optimal physical properties are obtained with a much smaller proportion of combined (acetone insoluble) sulphur than in the case of

non-accelerated mixings. This fact has been cited as unfavourable to the chemical theory of vulcanisation. It is known, however, that the optimal properties of a non-accelerated mixing depend on the conditions of vulcanising, and when speaking of reversion I pointed out that two samples with the same percentage of combined sulphur might have different physical properties. Moreover, pretreatment as in milling, if excessive, brings about a difference in the relationship of coefficient and physical properties. The low coefficients of accelerated vulcanisates may be accounted for by taking into consideration the low temperature and short period of heating.

The case is analogous to reversion, but in the opposite sense. The rubber reaches its maximal physical properties with a smaller proportion of combined sulphur because the stiffening effect of the caoutchouc sulphide is less modified by the degrading effect of heat. It is also possible to imagine a difference in the distribution or size of the micelle of the caoutchouc sulphide which I have suggested as descriptive of the structure of vulcanised rubber. This will account for the better physical properties of the accelerated vulcanisate. Some recent experiments I have in hand tend to support this view.

The protagonists of the adsorption theory have to some extent shifted their ground in recent years. It is now generally admitted that actual combination of rubber and sulphur takes places, but it is claimed that this is a secondary phenomenon. The main effect is said to be due to the adsorption of the sulphur, the subsequent chemical combination having little or no significance.

(3) *Weber believed that a series of caoutchouc-sulphur compounds were formed when rubber was vulcanised. As none of these can be isolated, and there appears to be no evidenc: of the existence either of a primary or a final member of the series, there is no analogy with a series of chemical reactions.*

Weber's theory of a series of caoutchouc sulphides is not now accepted. As shown above, the fully vulcanised product has a definite composition, and the intermediate products will consist of physical aggregates of caoutchouc and the sulphide in conformity with the two-phased structure of vulcanised rubber. So little is known as to how this type of colloid is built up that it is rash to venture on theories in explanation of its structure, but if we can conceive of a plastic and a rigid phase, the former due to the presence of the caoutchouc and the latter to the sulphide, we have an interpretation, I cannot say explanation, of the gradual loss of extensibility and corresponding gain in rigidity as the proportion of combined sulphur increases. The limiting member will consist almost entirely of the rigid phase.

If we adopt the micelle theory which is being exploited to visualise the changes which take place in cognate colloids such as soap and gelatine, we may conceive of a network of rod-like particles of the rigid phase of extreme tenuity which will enclose the non-rigid phase. A very small proportion, only one to two per cent. of the rigid phase corresponding to ½ per cent. of combined sulphur suffices to prevent appreciable dispersion of the vulcanised rubber in a solvent such as benzene in 24 hours. With 10 per cent. of the rigid phase we have a vulcanised rubber with a coefficient of three which swells, but is not dispersed by solvents, but yet preserves its tensile properties. With 16 or 17 per cent. of the rigid phase the maximal physical properties are reached although the distensibility is already somewhat reduced and falls below 1,000 per cent. at breaking point. Similarly with the swelling of the vulcanised rubber in a solvent this will naturally be reduced with decreasing proportion of the plastic phase and increasing rigidity of the solid phase, and with 20 or 30 per cent. of the latter, swelling becomes very small. The swelling of vulcanite in solvents is probably due to partial decomposition during manufacture owing to the degrading effect of the heat. Some preliminary experiments indicate that with accelerators and consequent shorter heating, the swelling is reduced.

(4) *The sorption of sulphur rises with the temperature, and the temperature coefficient is in better agreement with an adsorption process than with a chemical addition reaction.*

The temperature coefficient based on numerous determinations which have been dicussed in an earlier lecture are in accordance with the chemical interpretation, being of the order of 2½ units for every 10 deg. rise. Ostwald's conclusions were based on false data.

(5) *The sorption of sulphur does not proceed in a regular manner, the curves show various irregularities such as are often met with in the case of adsorption processes.*

The irregularity of the vulcanisation curves do not exist when experiments are made with sufficient precautions.

(6) *From the data of Hübner and Stern, curves can be drawn typical of adsorption.*

Here again, incorrect data gave rise to the conclusions drawn by Ostwald. Spence's curves show that vulcanisation proceeds at a uniform speed provided that sufficient sulphur be present. I have referred to the divergence shown by some of the graphs, which show curvature to varying extents which in some cases is very marked. This may be atrributed to the action of accelerators, natural or artificial, present in the rubber. Spence used carefully extracted rubber, while other investigators have used raw rubber as prepared without preliminary treatment.

The cause of the divergence is not capable of explanation in all cases. Thus, it is not clear why smoked sheet should give curves approximating to straight lines, although

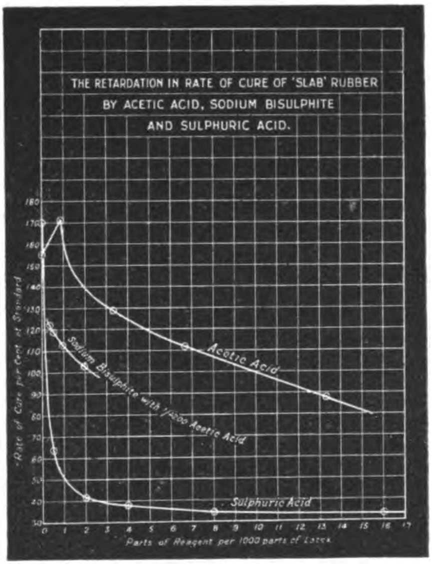


Fig. 19.

rubber in this form retains an appreciable quantity of the latex serum. Possibly the antiseptic action of smoke inhibits the formation of the natural accelerator, the relatively fast vulcanising property being attributed to the large proportion of serum retained. On the other hand, it is found that crepe rubber shows considerable variation in the curvature of the vulcanisation graphs, and this is especially pronounced in the case of fast curing crepe prepared from matured rubber and containing a relatively large proportion of the natural accelerator.

Although smoked sheet rubber in general vulcanises a little faster than pale crepe, it is quite out of the running when contrasted with crepe from matured latex. This latter will sometimes vulcanise twice as fast as ordinary pale crepe rubber when tested in the form of a rubber sulphur compounded mixture in the proportion of 9 to 1. On the other hand, the use of an excess of acid, in particular a strong acid, for coagulation neutralises the effect of the natural accelerator or retards its formation.

Fig. 19 shows the curves for acetic acid, the same with the addition of sodium bisulphite and also for sulphuric acid. Fig. 20 shows a similar series, but parts of coagu-

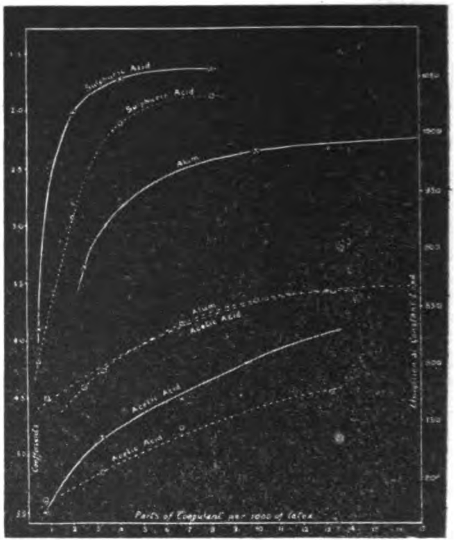


Fig. 20

lant are plotted against coefficients. In each the coagulum was allowed to putrefy before washing and crepeing, so that with the minimum proportion of acid a rapid vulcanising rubber is formed and the effect of additional acid is more marked than in the case of ordinarily prepared crepe rubber. All these curves you will note refer to the rate of cure as measured by the amount of sulphur combining with the rubber in a given period. Similar, although not identical, curves are given if the elongation at a given load be taken in the place of the sulphur figures.

Some years ago a very comprehensive

series of sulphur determinations were made by Skellon over a wide range of specimens vulcanised to varying degrees. These figures have been studied by van Rossem, who has constructed graphs to show the rate of combination of rubber and sulphur with varying proportions of sulphur in the different mixings. These are shown in fig. 21. You will note that up to 50 per cent. of sulphur entered into combination with the rubber. There are not many determinations for the higher proportions of sulphur, but there is no doubt as to the general course of the curves, as Skellon has determined the combined sulphur over a full range in one or two other instances.

It will be noted that the curve for a 10 per cent. sulphur mixing is almost rectilinear.

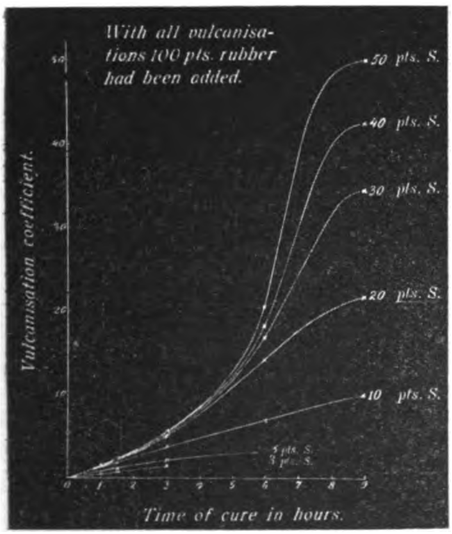
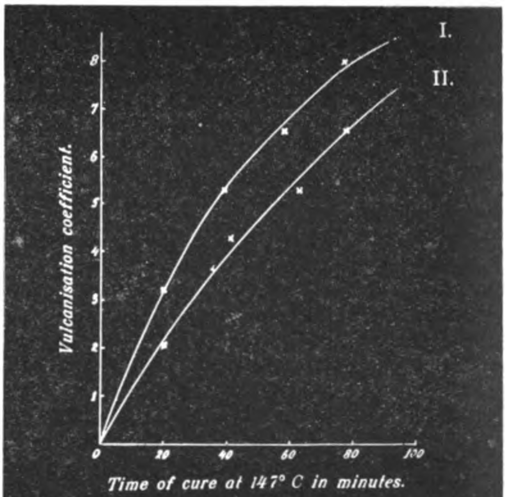


FIG. 21

With smaller and larger proportions there is more curvature, but this is not pronounced until the 20 per cent. sulphur mixing is reached. In the second place, it will be seen that the curves for the higher proportions of sulphur, that is, 20 to 50 per cent., follow the same course in the initial stages. These characteristics are attributed to the limited solubility of sulphur in rubber which is estimated at 10 per cent. Consequently, in the initial stages vulcanisation will proceed at the same rate whatever the excess of sulphur over 10 per cent. As, however, sulphur is more soluble in vulcanised than in raw rubber it follows that as vulcanisation proceeds more sulphur dissolves and is available for reaction. As the last residues of sulphur combine, the rate of reaction is reduced and consequently at the end points the curves take a horizontal course.

This should apply to all the curves whatever the proportion of sulphur initially present. It is hardly noticeable in the case of the 10 per cent. sulphur mixing, but this may be attributed to the scale of the diagrams and the more horizontal position of the curve as compared for instance, with Spence's curves as shown in the first lecture.

It seems, therefore, that a 10 per cent. sulphur mixing gives a rectilinear vulcanisation curve provided that no accelerator, natural or artificial, be present. I refer again to fig. 5, showing the curves for smoked sheet and crepe rubber taken from my own experiments. The lines are almost rectilinear. The effect of artificial accelerators has already been discussed, but in conclusion I give one more figure (22) from a different source



I. 100 pts. rubber + 8.1 pts. sulphur + 0.5 pts. accelerene.
II. 100 pts. rubber + 8.1 pts. sulphur + 0.25 pts. accelerene.

FIG 22.

illustrating the effect of different proportions of accelerene (p-nitroso dimethylaniline) which shows the curvilinear character of the vulcanisation curves due to the action of the accelerator. Both refer to 10 per cent. mixings of rubber and sulphur; I contains 1 per cent. of the accelerator and II ½ per cent.

OBITUARY.

Sir Henry Evan Murchison James, K.C.I.E., C.S.I.—Sir Evan James died on August 20th at his residence, Glenshee, Twickenham, at the age of seventy-seven. The eldest surviving son of William Edward James, D.L., of Barrock Park, Cumberland, he was educated at the Cathedral School, Carlisle, and the Grammar School, Durham, and passed the Indian Civil Service Examination in 1864. He went out to India in the following year, being posted to the Presidency of Bombay. After filling various subordinate positions he joined the Secretariat as an Under-Secretary to the Local Government. Later he became successively Postmaster-General of Bombay, Postmaster-General of Bengal and Acting Director-General of the Post Office in India. Subsequently he reverted to district work in Bombay and in 1890 was chosen by the then Governor of the Western Presidency, Lord Harris, to succeed Sir Arthur Trevor as Commissioner in Sind, an office once held by that celebrated administrator, the late Sir Bartle Frere. While in control in Sind, Sir Evan James initiated the experiment of colonising some of the lands brought within the influence of an irrigation work which had just been completed, the Jamrao Canal, with cultivators from the congested districts of the Panjab—Baluchis, Marwaris, Cutchis, etc. A feature of Sir Evan James's scheme was a stipulation that the conditions of the tenures should provide against mortgages of the lands of the new occupants. This, as the late Mr. Herbert Birdwood pointed out in the paper on "The Province of Sind," read by him before the Society in 1903 was only one of many good works by which Sir Evan won the gratitude of the people of Sind. On his retirement from the service in 1900 the Bombay Government expressed in the following terms their appreciation of his work :—"By his indefatigable activity, industry, his zeal for the amelioration of the condition of the people, and by his consistent maintenance of a high standard of public duty, Sir Evan James has set a valuable example. To his able and vigorous administration is due in no small measure the unbroken development of the Province of Sind and of its Port of Karachi." He was devoted to travelling and exploration. He discovered the sources of the Sungari, an account of this journey being given by him in his work entitled "The Long White Mountain, or, Travels in Manchuria." He was elected a fellow of the Royal Society of Arts in 1908 and since 1916 had been an active and valued member of the Indian Section Committee.

SWALLOW'S NEST.

Swallow's nest is, according to the Chinese Government Bureau of Economic Information, prized by the people of China for its supposed medicinal value. It is said to be efficacious in curing lung diseases and small-pox. The article is also considered to be a table delicacy, and a sumptuous Chinese dinner is not complete unless there is a dish of this, to the Chinese taste, palatable food. There are two varieties of swallow's nest, the kwan yen or white variety, and the mao yen or feathered variety. The latter is so called because the texture of the nest is generally mixed with the bird's feathers. Swallow's nest is produced chiefly in the vicinity of the Malay Archipelago, including Borneo, Sumatra, Java and the Philippine Islands. It is found in Changchow and Chuanchow in Fukien, especially on the reefs or islets off the coast of Changpu. Swallows of the common species, the house-martin, make their nests of mud and straw, but the sea swallow builds its nest in the rocks of the cliffs, using a fluid-like substance emitted from its salivary glands. The popular belief that it is made of a kind of jelly-fish or a kind of seaweed. is not admitted by scientists, because under the magnifying glass the substance contains no trace of either vegetable or living cells.

Miss C. T. Wang, a Chinese student in America, has made an extensive study of the nature of the swallow's nest. She has found by chemical analysis that the pure substance of the swallow's nest contains 2.52 per cent. of carbonate, which, when solved in hydrochloric acid, yields 0.035 per cent. of phosphorus and 1 per cent. of sulphur.

The swallow's nest is rich in albuminous matter. There is a variety of albumens contained in the nest, in which the percentage of nitrogen varies from 3.39 to 24.6 per cent.

As a food, the nest is digestible by both the digestive ferment from the salivary glands and the gastric juice, but the process of digestion is not so easy as with hard boiled eggs. For nourishment, its value is questionable, since the albumen contained in the nest is not an adequate substitute for the necessary albumen contained in other foodstuffs.

GENERAL NOTE.

Efforts to Promote Victorian Tobacco Industry.—The State of Victoria is showing great interest in tobacco cultivation. For several years, writes the United States Consul-General at Melbourne, attempts have been made to increase the production and to improve the quality of domestic tobacco, in order to reduce the tobacco imports into Australia. These efforts, however, have been unsuccessful, principally because the growers are unfamiliar with the proper methods of culture and curing the leaf. The State authorities have recently commissioned Mr. Temple Smith to proceed to the United States for the purpose of inducing at least 12 American tobacco growers to emigrate to the Commonwealth with the object of demonstrating to Australian farmers the proper methods of cultivation and curing tobacco.

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FRIDAY, SEPTEMBER 7, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICES.

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Lord Blyth (Chairman of the Committee).
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PROCEEDINGS OF THE SOCIETY.

TWENTY-FIRST ORDINARY MEETING.

WEDNESDAY, 30TH MAY, 1923.

MR. L. BERESFORD SEYLER, in the Chair.

The paper read was:

THE HISTORY OF CHILDREN'S AND INVALIDS' CARRIAGES.

By SAMUEL J. SEWELL.

The physicians of all countries agree that a woman is not fitted by nature to carry a babe in her arms, on her back, nor on her head or shoulders—these are injurious to both. Hence the need of a miniature carriage.

Such vehicles are generally called perambulators or bassinettes.

That nomenclature is, I must admit, unsatisfactory, since the first name comes from *per* and *ambulare*, meaning to walk through or over, and thus it is the person who wheels the vehicle who is the perambulator according to our best dictionaries, and not the carriage itself. And as to "bassinette," that is French for a cradle made of wicker, and wood is the material mostly used for the bodies.

I shall, then, use the term "pram" for the vehicle.

It is passing strange that, although 3,000,000 are in use in this country, and they have been an inestimable boon to both mother and child, no one has hitherto attempted to give the history of prams. In stepping, not rushing, in, then, where others fear to tread, and in spite of enormous correspondence and investigation, and having for thirty-eight years edited a journal for the trade, I shall welcome the fullest criticism.

As regards origin, British manufacturers, knowing that for over a century this country has led the world in the construction of miniature carriages, are prone to think that we were the pioneers. That is not true, although one cannot say when the first pram was made, and by whom. Proof of this is found in several books, notably in that on toys by Mrs. F. Neville Jackson, published by "Country Life" in 1908, and now, alas, out of print. That gifted writer tells us that "glancing at the toy world of the past is like looking at history through a diminishing glass; we can see things exactly reproduced in miniature," and she advances the proposition that the "basis of the toy is mimicry." If we accept this, as I do, and owing to the discovery in Athens of baked clay toys fitted with wheels, we are entitled to assume that a primitive form of child's carriage was in use several centuries before the Christian era. But history appears to be silent as to what happened in development until the fourteenth century, when a Chinese child's chair on four wheels, drawn by rope, was painted by a Japanese artist. And there exists a drawing showing a wooden frame on wheels, for teaching a child to walk, which was made in the fifteenth century, and Lancret painted a similar device as used in France in the eighteenth century, but with the child actually being wheeled.

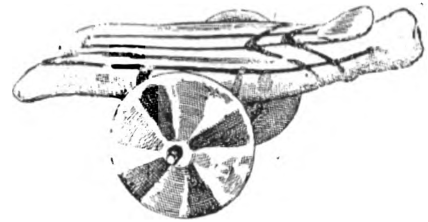
As to Egypt, I learn from Professor E. Newberry and Professor Elliot Smith, both great authorities, that there is no evidence of the early use in that country of carriages for children. But both in India and Ceylon toy miniature carts have been known for centuries.

Next, as to Britain, we appear to have utterly ignored the existence in other countries of prams for transport or play, and the precursor of our pram would seem to have been the humble "hop wagon" used in Kent for centuries by hop and fruit pickers for the carrying of cooking utensils and food to their place of labour. It is known that mothers used to place their children in this wagon, which, at first, was little else than a rough box fastened to axles of wood which engaged with four wheels of similar material. In the early part of last century several of the makers in London made improvements from time to time, but these wagons were never upholstered or fitted with springs, and they were then called "stick wagons." But townspeople rarely bought them, and, as they were drawn by a handle, the child might easily fall out unnoticed. Before the 'fifties the trade in these wagons all but ceased in favour of another style of pram.

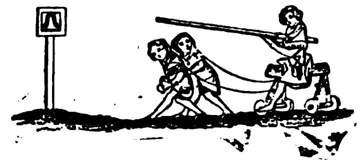
In the meantime, in 1780, there were built for Lady Georgina Dorothy Cavendish, the eldest daughter of the fifth Duke of Devonshire, two carriages by a coachbuilder whose name is no longer remembered, and they were certainly remarkable. These are still to be seen at Chatsworth in a perfect state of preservation, and are, I believe,

Carriage made for Lady Georgina Dorothy Cavendish in 1780.
(*Copyright of the Duke of Devonshire.*)

Domestic scene in 1493.



The first pram known. Model of clay. Discovered in Athens. Supposed to be 3,000 years old.



Tilting by boys in the fourteenth century.

Chinese chair on wheels, of the fourteenth century.
From a painting.

not only the oldest prams in existence but also the finest ever made.

The most interesting is the one constructed to imitate a C-spring and perch coach, except as regards the body, which approximates to that used later for the three-wheel pram. It has four wheels, 18in. and 12in., of wood, ironshod, wooden axles, a canopy of leather, luxurious upholstery in which fine printed linen is used, and a handle for drawing the carriage.

The second pram was drawn by a small animal, the collar for which still exists, and the body, similar in shape to the other vehicle, has four similar wheels, 21in. and 18in., and a three-quarter lock. The body suggests a scalloped shell of bronze, and there is a detachable apron of like material and fashioning. The under-carriage is most fantastic, depicting the Cavendish snakes, which form part of the Devonshire family crest, and they are linked up with the springs in a curious manner.

These carriages, built in 1780, were, probably, never used outside Chatsworth, or their maker would have built up a big trade as the first manufacturer of a pram which was safe, comfortable and artistic.

Their one defect, however, was that they had to be drawn—their builder could not get away from the idea of horse-traction—and it was not until sixty years later that a pram was fitted with a handle at back, instead of a pole in front, and could then be pushed and the occupant kept under observation.

In 1840 several men took up the manufacture on a small scale of a three-wheel vehicle, which they called a child's carriage, notably John Allen, of Hackney Road, E., and A. Babin, of New Street, E.C., and they found that the London people were now open to buy prams. Success caused others to enter the trade, particularly Charles Burton, who in 1853 took out the first patent for prams in this or any other country. There never has been a "master patent," the nearest approach to such being the suspension of the body by T. Simpson in 1887 from two handles, and the outside spring chassis of Charles Thompson in the same year.

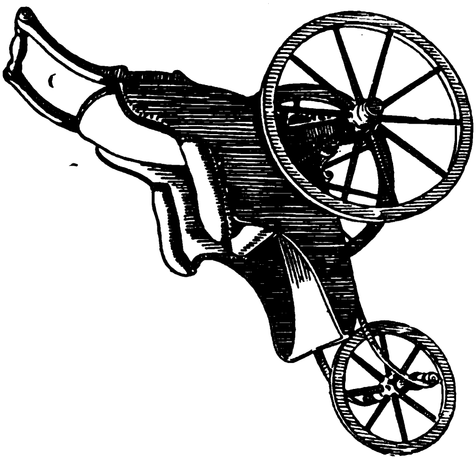
In 1843, Babin and Ripkey and John Allen were the only makers of "child's carriages."

By 1850, the makers numbered four, owing to William Parker, founder of Parker Bros., of Curtain Road, E.C., joining the ranks, and he is one of the several who lay claim to having first used the word "perambulator."

In 1852 Charles Burton started a small factory in Hampstead, and here constructed a pram according to his, the very first, patent, dated 1853, and opened a showroom in Oxford Street, London, and in a district which within three years became the centre of the trade. In 1856, there were four shops devoted to what were now called "perambulators," and all within a few hundred yards of Burton's showroom, and no fewer than 20 makers in all London.

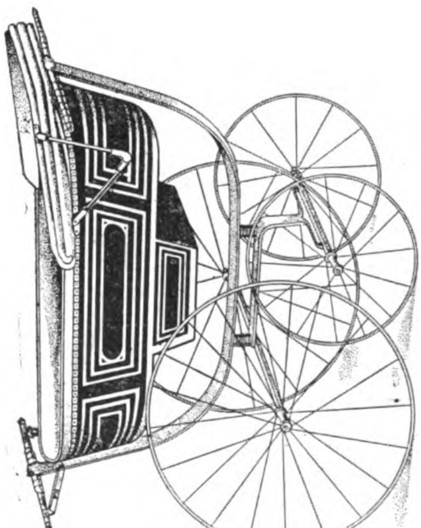
Burton appears to have considered his folding device the most important feature in his patent, and the other makers left this alone but copied some of his ideas or improved on them, particularly J. R. Frampton, who, in addition to chairs, made in Trinity Street, S.E., "stick wagons." On seeing the Burton patent pram in 1853, he decided to improve the three-wheeler, and constructed his wheels with metal for the hubs and spokes and gave them half-round iron tyres and iron handles. His son, Louis Frampton, still alive, remembers the first of these prams, in which he was placed for a trial trip in South London. A big crowd surrounded the pram, and orders for it at once flowed in, mostly from the working classes, who hitherto had not been purchasers of real prams. It might also be stated that at Frampton's factory, in 1862, was made by the workers as a gift to their employer's daughter, the first toy pram—the first and only one made there since Mr. Frampton thought that no trade was to be done in such "nonsense," as he called it. That estimate was appallingly wrong, since the production of toy prams was soon started by others and the output became, and still is, enormous. However, Frampton was one of the most successful of the pram manufacturers of all times, he retiring before the 'eighties to live in Belgium, in which country he is said to have been shot during the late war. His pram factory in the Borough was sold by auction in 1880, but his descendants still deal in pram fittings in Ipswich.

Returning to the year 1855, James Monk, who had acted as foreman at Burton's factory, started making prams in Winsley Street, W., later removing to Oxford Street. Since 1881, as W. Monk & Co., this business has been carried on at Bath, first by the son of the founder, who still lives, and it

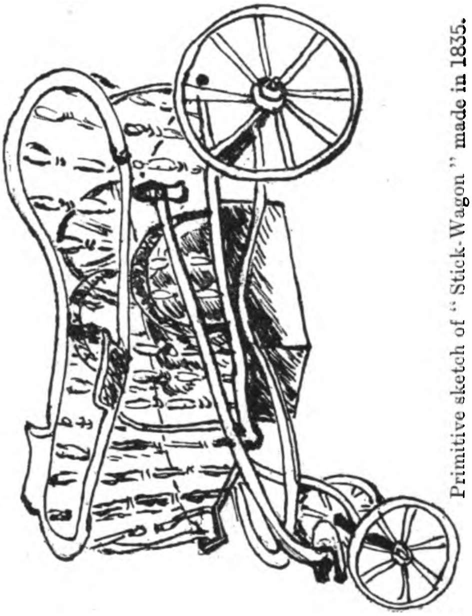


The first three-wheeler. Made in 1840.

Play of the eighteenth century. From a print of Chodowiecki.



The first pram with suspension body. Patented by Simpson, Fawcett & Co., in 1887.



Primitive sketch of "Stick-Wagon" made in 1835.

is now conducted by W. H. Monk, the grandson. This firm own the Bath Chair Factory started by James Heath, the inventor of the original bath chair, in 1829, and in it was made the "Prize Bath Chair," which, exhibited in the great London Exhibition of 1851, was bought by Queen Victoria and presented to the Empress of the French.

The only concerns which existed in 1856 and survive are Parker Bros., of London; W. Monk & Co., now of Bath; Leon L'Hollier, now known as Thomas McKenzie, of Birmingham; John Dove, of Glasgow; Trotman, of Holloway, having closed down last year.

But there are several pram manufacturers who date back some 40 or more years as follows:—London: Presland & Sons (1858), W. J. Harris & Co., Ltd. (1880), Simmons (1883), Dalston Baby Carriage Co., Ltd. (1883), Lines of Tottenham (1869), and Star Manufacturing Co. (1886). Bristol: Smith (1850), and Twiggs (1877). Birmingham: Harris (1870), Jas. Lloyd & Co., Ltd. (1874), W. H. Dunkley (1882). Leeds: Myers (1876) and Wilson (1877). Nottingham: Hardstaff (1858), J. Green & Co., Ltd. (1874). Oldham: Bradbury & Co., Ltd. (1885). Several manufacturers go back nearly 30 years, such as Rothschild & Baker, of Birmingham, but of the total existing makers, 50 per cent. started within the past 25 years.

One word as to the mail cart, which originated in Leeds in 1886 at the factory of Simpson, Fawcett & Co., and shortly after was also made by Wm. Wilson & Sons, of the same city, and later by other firms. It was introduced as a plaything for boys and girls, but since mothers persisted in using it as a vehicle for infants, many patents were taken out to make it available as both a pram and a car. The sales for some fifteen years were enormous, and then dropped to so small a figure that most pram makers now ignore mail carts.

As to U.S., the duty has been so much against us as to restrict imports, although the American pram is an inartistic, uncomfortable vehicle compared with our own. Formerly, its body was made of cane or other vegetable product, but of late years of wire, covered with a solution and woven by a machine constructed under Lloyd's patent. That class of pram, however, scarcely suits British tastes, yet it is made here at Lusty's factory in Bromley-by-Bow.

But it is only fair to say that to America is due the invention, in 1904, of an ingenious metal folding car, of which, before the war, many thousands came to this country. It was found, however, that these could be produced more cheaply in this country, and then firms opened factories in Birmingham and Leeds. Further, they made substantial improvements, notably Messrs. Headley, Baker & Giles, and we now not only supply ourselves but also export such metal folders.

But our export trade was killed by the war, so steps are now being taken to regain it. Yet the heavy cost of transport, rail or shipping, are tremendous obstacles to its expansion. Could transport be reduced 50 per cent., which is not unreasonable, then an export trade of a million prams a year should be quite possible. Cheaper transport rates are being agitated for by the Pram Manufacturers' Association, a thoroughly representative body, whose main efforts are devoted to cheapening the cost to the buyer.

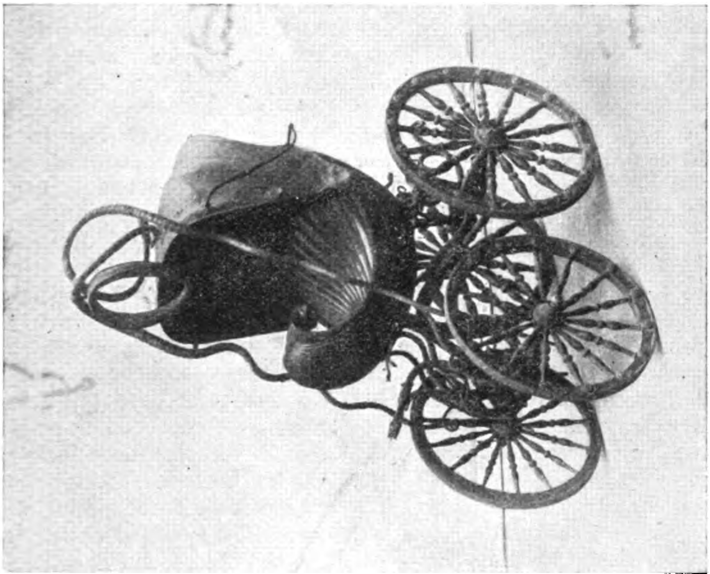
Of the 200 big and little pram manufacturers, one-sixth have factories equipped with the latest and best machinery, also up-to-date office arrangements, and they need not fear comparison with any other industry. In a word, our pram manufacturers are efficient, enterprising, industrious, charge only a reasonable rate of profit and fully deserve that their art, employing many thousands of hands, shall continue to prosper.

What becomes of old prams, of which 50,000 at least, are discarded by users every year? As regards 50 per cent., these are renovated and live again, and as to the remainder ask the boys with sufficient ingenuity to wed the wheels to soap boxes.

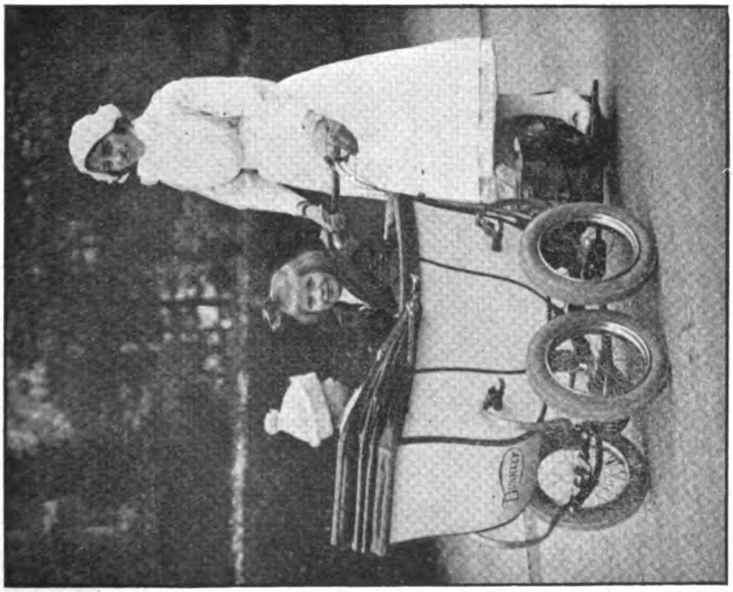
Experience shows, however, that for the first-born even the poorest mother insists on a new pram, and that she wants one different from her neighbours.

Hence, the pram manufacturer is ever thinking of new designs, new colours, new kinds of upholstery, and the makers of wheels, springs, fittings, leather cloth, etc., are ever kept at inventive point.

Who starts the fashion? The honours are divided. The public say: "I should buy that were so-and-so altered." "Then," says the dealer, "it shall be done," and an order goes to the factory, and not to lose trade, the maker has to change his designs, already, perhaps, numbering 100, and the



Animal-drawn Carriage made for Lady Georgina Dorothy Cavendish in 1780.
(Copyright of the Duke of Devonshire).



The first petrol-motor pram for both nurse and children.
Patented by W. H. Dunkley, in 1921.

pram so produced catches on and other dealers want it. But thousands of pounds have been lost to the makers through catering to a passing whim and then building up a stock which becomes unsaleable.

Yet, with all their troubles, and they are not few or light, pram makers are long-lived, as, too, are their workpeople. There still lives, and over ninety, Mr. S. T. Fawcett, of Simpson & Fawcett—the grand old man of the trade ; and Mr. Simmons is now over seventy, not to mention a half-dozen other manufacturers who have passed the sixty mark. And in the factories it is common to find hands who have worked for their firm over forty years, yet still take a delight in their tasks.

But I cannot recall more than a half-dozen of the 250 firms who have made prams who acquired even small fortunes, and dealers who sell even twenty prams a week are few in number.

Since prams are largely sold through catalogues, thirty years ago it used to be said that those who sent out the best illustrated lists made the worst prams. But none can say this to-day.

Not only for prams, but also for their wheels, fittings, tyres and canopies is Britain famed, and our export of these parts, great before the war, is now on the increase—there is nothing made abroad which will compare with them.

As regards Scotland, prams were first made in Stirling in 1856, in a factory now closed, and the oldest Scottish maker is now John Dove, who started in 1850.

Ireland has never done much in pram making, but has a small factory in Londonderry.

Wales produces but few prams, and these at Cardiff.

The Ideal Pram.

Now as to how a pram should be constructed, and I will here quote the opinion of Dr. Eric C. Pritchard, a Harley Street physician who has for years specialised in children's welfare. He says that until seven or eight months' old a child should be allowed to lie down in its pram, and after that should be induced to sit. Hence the necessity of a well. The body of the pram should be upholstered to provide comfort, and the material used should be of such a nature that it can be easily cleansed. As to the springs, these should be so elastic that no shocks or jars are conveyed to either infant or mother, and the body should be so attached to the chassis that the pram cannot be overturned by the child. Lastly, the pram should be easy for the mother to propel, and it is eminently desirable that a brake be provided and that this be automatic.

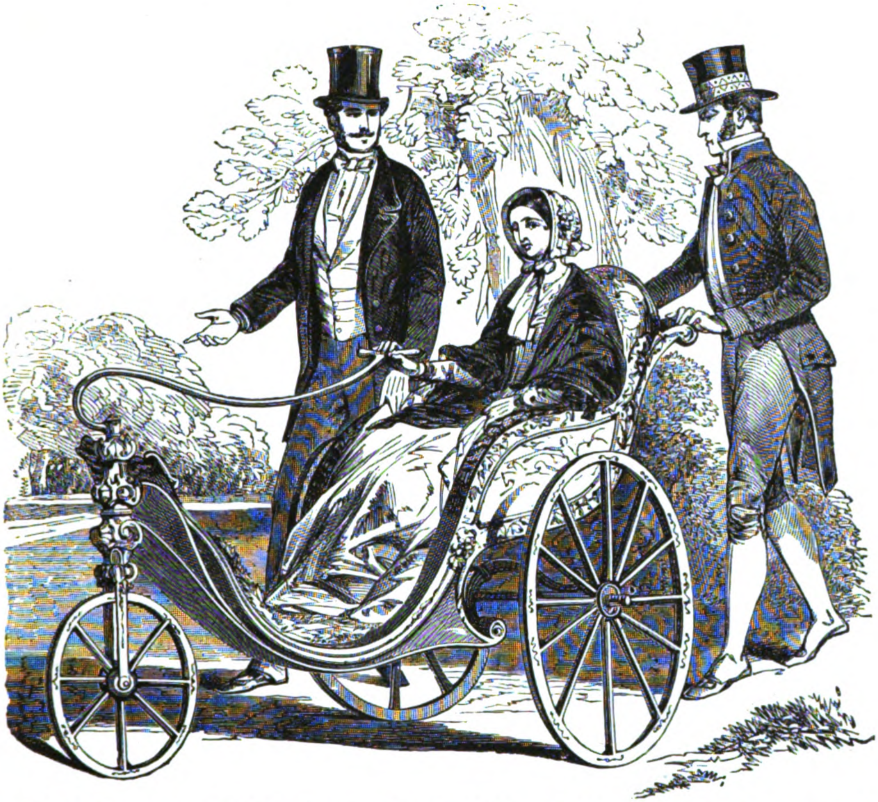
If we take this expert's specification as correct, and then study how far our pram manufacturers have worked to it, we must agree they have done much, and that the ideal pram no longer exists in theory but in actual practice. Indeed, I know of no device in the world which, starting so humbly, has been developed to a higher standard of perfection. For proof, go to any pram dealer who is properly stocked—and there are 5,000 of them—and examine his carriages, and note the prices, which are amazingly low when the cost of production, of which nearly half is in raw material, is considered. Really, this country has every reason to be proud of its pram industry, which is unequalled by any other country, and outside our Empire there are a dozen countries in which prams are made. Germany, before the war, tried to sell to Britain, but both her designs and her prices were too unsatisfactory. France has for many years been an importer of British prams, although she started making herself a small, slender chair with wheels in the 'fifties, and has since copied English designs.

Development.

With the able assistance of my sub-editor, Mr. J. R. Francis, nearly 2,000 patents have been examined with the view to, may I say, tracing the oak from the acorn. The specifications comprised over 8,000 pages and 5,000 drawings and, although we have compressed the result into the smallest possible compass, it would take three hours to read what we have compiled. I, therefore, propose to merely give you a short survey, but shall be pleased to supply a copy of our full report if desired.

The need for compression is obvious when it is further stated that down to April 30th, 1,198 pram patents had been taken out by almost as many persons, and that the patentees had placed them in 25 sections.

But I feel that I must mention the names of a few of those who have contributed to the art of miniature carriage building. First, as to those who have passed away—Charles Burton (the first patentee), T.



A Royal Invalid Carriage. Exhibited at the Great Exhibition, 1851. Bought by Queen Victoria and Presented to Empress of the French. Made by Jas. Heath (W. Monk & Co.), Bath.

Grant, John Harrop, James Lloyd, Leon L'Hollier, W. Hatchman and George H. C. Hughes—the last mentioned much cheapened and improved the pram wheel and founded the largest pram wheel business in the world. Then G. Lines, W. J. and E. G. Parker, G. R. Price, H. E. Reinhold, J. Stone, James Smith, W. J. Harris, J. Starley and W. Wilson.

Next as to those who survive, and I might first mention those who have more than a dozen patents to their credit, these being: S. T. Fawcett and his co-adjudicators, the Messrs. Simpson & Dow (40), W. H. Dunkley (31), H. V. Baker (20), and F. Headley (14). The others are: Thomas F. Simmons, E. Atkins, A. R. H. Baveystock, T. H. Cole, W. H. Ball, W. H. Brassington, W. and W. E. Ashton, C. E. Cowtan, A. Craven, W. J. Harris & Co., H. I. & E. J. Humphry, H. S. Jarvis, T. H. Brooke-Hitching, F. O. Harland, W. J. Fieldhouse, S. & F. Hodgetts, F. N. Giles, H. B. Murdoch, W. Lines, J. Lines, H. Hodges, F. C. Mathieson, Nelville Smith, A. E. Robotham, E. O. Robathan, L. B. & L. G. Seyler, J. W. & A. Wilson, H. Sillers, H. W. Twiggs, E. Taylor, O. O. Richards, S. Rones, C. T. Clover, W. T. Gower, C. S. Farris, G. F. Hubner, H. E. Salmon, Bradbury & Co., W. Saward, John Hampson, F. A. Cartwright, H. L. Gledhill, W. S. Dove and E. T. Morriss. Should I have missed anyone who deserves mention, it is by oversight and absolutely unintentional.

I shall now attempt to give in a few words the trend of invention.

Head Rests.—The first patent was taken out by Saunders in 1884, he being one of four patentees who aimed at comfort and adjustability.

Sanitary Devices.—The public have always considered these as unnecessary, but the first patent was in 1883, by E. Sandow, who proposed to use a "medicated medium" and a ventilating fan driven by clockwork. Some proposed detachable upholstery.

Mudgards and Umbrella Holders.—As to the first, there have been six patents, starting in 1884, although mudguards were in use 70 years ago. Umbrella holders have mostly consisted of hooks, sockets, rings or

baskets, and were first patented by Bond & Sadler in 1885, they attaching a hook and an eyelet to the side of the carriage. The latest form is of leather, and is retailed at 2s. 6d.

Security Devices.—At one time there were numerous accidents through children either falling out of, or overturning, their prams, and sometimes with fatal results. But our manufacturers have now made the pram so safe that, according to official returns, no fatal accident has taken place for several years. In the days of the three-wheeler, a thoughtful mother simply tied her child to its pram, but in 1884 Koopmann provided an adjustable belt, and since then there have been many inventions in that class, notably by E. O Robathan, J. P. Neville and C. Newman. In 1895, Paulsen and Moller patented the fitting of revolving balls at the top of the pram, so that when the child tried to rise, the balls would revolve as soon as it touched them, which prevented it rising. As showing the attention given to security devices, there have been 28 patents by 27 persons.

Wheels.—Since wheeled vehicles for passengers were not made in this country until after 1555, it is certain that no baby carriages, and, therefore, no pram wheels, were produced here until long after that date. The first patent for wheels for prams was taken out in 1855 by Wren, it being for securing the fore and hind wheels of a three-wheeler in such a way that they could be readily detached and the carriage folded. Since then patents for pram wheels and axles have been taken out to the number of 124 and by 97 persons, from which it is clear that only a few can be referred to. To start with, the first pram wheels were made entirely of wood, as, too, were the axles. Gradually iron axles and hubs were adopted, and hoop-iron encircled wooden felloes. In the early 'fifties J. R. Frampton used half-round iron for the tyres, and by the early 'seventies there were several firms making all-metal wheels, rubber tyred, for the trade. J. Starley, in 1874, patented a new method of mounting pram wheels on their axles, and George H. C. Hughes introduced an oil box, a protection for the spokes, and serrated tyres to prevent creeping. J. Fry introduced a method of casting hubs. In 1887 George H. C. Hughes conceived the idea of building satisfactory pram wheels at a much lower cost, and opened a factory in Birmingham, which still exists, and is the largest of its kind in the world, producing 125,000 wheels weekly ; there are now three other factories of smaller capacity making for the trade. After this date there were many patents for tightening the spokes, for improved lubrication, better methods of adjusting the axles, and several for disc wheels, not to mention others for ball bearings. As regards ball bearings, recent tests show that their advantage in the saving of labour in pushing a pram is considerable.

Then as to tyres, there have been many inventions, mostly for methods of securing, first, flat, and afterwards round, tyres to the rim. And pneumatics have been used, but it has been found that the public will not take the trouble to keep them inflated. The latest idea is to use spongy rubber known as the "Sorbo."

Springs.—There have been no fewer than 130 patents taken out by 94 persons in connexion with this department in pram construction. It should be understood that the two prams of the Duke of Devonshire, made in 1780, were fitted with metal springs, but there are no records that springs were again applied to prams until 50 years after. The first patent for a pram spring was that of W. C. Fuller, who, in 1855, used india-rubber, and in the following year Johnson coiled a flat strip of steel into a circle, using two such springs so that one was elongated whilst the other was contracted. Then came along a number of patents, Simpson & Fawcett, in 1887, suspending the body from two handles, and calling it a hammock carriage. In the same year there was patented by C. Thompson C springs which were fixed to the sides instead of the ends of the body, but that inventor met with small success as regards sales. Then we had several other ideas in pram springs, which also failed to attract, except such as were of the U-shaped suspension type. And we now arrive at 1916, when W. H. Dunkley took out his patent for side C springs from which the body was so supported that it could be brought nearer the ground than formerly. Had the late C. Thompson only thought of lower suspension and provided for it, his patent would have been the most important in the history of pram manufacture.

Since 1916 there have been other patents for outside C springs too numerous to detail. But another idea has recently

taken root, which is to use coil springs to support the body, the latest of which is to make such springs of conical shape in order to allow of elasticity in every direction.

BRAKES.—There have been cases where prams have run away and the occupant been killed, but according to official returns these do not number one a year for the whole country. No statistics are compiled unless there is a fatal accident Beyond question, a brake which acts automatically is a great safeguard, but the experience of the pram trade is that the public do not want automatic brakes because they involve the holding off of the brake, when the carriage is wheeled, by a cord or lever, and although there have been 94 patents, by 90 inventors, most of the devices being practical and inexpensive, the only type which the public will buy, as a rule, is a clip for the wheel, which, of course, is not automatic.

HANDLES AND SHAFTS.—In mail cart days folding shafts were almost a necessity, and J. M. Wilson's patent of 1894 sold in thousands. As to carriages, H. Lloyd was the first, in 1865, to hinge the handle, but this is no longer done. There have been many inventions for reversible handles, for example that of W. H. Dunkley in 1894, and the methods of fixing the handles have been legion, such as within the levers, extending beyond them, and the making of the handles telescopic. And as regards material, they were first of wood, then of metal, porcelain, cork, vulcanite, and, to-day, celluloid is in great use. But the tendency is to fit the handle levers to the chassis and not to the body, and to use U-shaped suspension frames. There have been 86 patents taken out in this section by 80 inventors.

HOODS, CANOPIES, APRONS, ETC.—Although both of the Duke of Devonshire's baby carriages were fitted with excellent hoods, it does not appear that these were applied to other makes until the 'thirties, and the first patent, dated 1858, is by Thornber, and it had a semi-circular body into which retired a covered semi-circular frame when not required. In the 'sixties the hood, much like it is to-day, made its appearance and, ten years later, improvements were introduced in the holders for canopies. Perhaps one of the most interesting of recent inventions in this line was that of Muckett, in 1908, for a combination hood and canopy, the former of waterproof material fitting over holland, with simple means for separating them, and it is curious to note that during the war a second patent for a rigid hood to retire within the body was effected.

POWER PROPULSION.—No fewer than 16 patents have been taken out for devices for rendering it unnecessary to push or pull a pram or invalid carriage. The first was in 1769, by Francis Moore, who, without giving any details, proposed to "use fire, water or air." In 1869, Chambers used cranks on the front wheel of a three-wheeler, and in 1888, Plant and Brown fitted to prams and invalid carriages a spring motor, Garvey in the next year using a hand lever in combination with a crank. S. Johnson, in 1892, applied tricycle mechanism to a bath chair, and Schreiger produced a pram which was propelled by the child alternately sitting and standing. The most useful of self-propelled carriages now existing, however, would seem to be the one using an electric motor made by Carters, and that driven by a petrol motor made by Dunkley. The latter is constructed to accommodate the nurse as well as the occupant of the carriage, but since the price of these motor carriages is £100 or so, the market for them is very limited, and they are not allowed to travel on the pathway, and require a licence. In 1916, G. C. Kennedy patented a canoe-shaped carriage for children and invalids who propelled themselves by rocking the seat.

VARIABLE BODIES.—By this I mean inventions for folding, converting, adjusting and reversing. No fewer than 367 patents have been taken out in these classes, and by 279 persons. Most of them had reference to the mail-cart, which started in popularity in 1886, but went out of favour 15 years ago, and since the sales to-day are very few, I need only remark that the patentees aimed mainly at making the cart convertible so that it could be used for one child to lie down and the other to sit, or for them to face or back each other. Of course, many patents were taken out for the wooden folder, which is still sold in large quantities, the idea being to make riding easier and to permit of, what it only was at the start, a folding chair on wheels blossoming into a substitute for a carriage. Yet I must assert that this object has not been satisfactorily attained. In 1904 there was taken out a patent by an American for a steel folder, the wheels of which contracted under the body. That was called the "Allwin," and a few months

later another American brought out different mechanism, his car being called the "Sturgis." Both of these cars were imported in large numbers, and then three Englishmen, F. H. Headley, H. V. Baker and F. N. Giles, introduced improvements, and the import has ceased for many years. Indeed, of the million of these cars now in use in this country, fully 95 per cent. were made here.

Passing now to carriages, as distinct from cars or carts which could be folded without anything being detached, the first patent was taken out in 1855, by H. Nunn, that applying to a three-wheeler, and there were numerous other inventions in connexion with that pram for doubling its capacity or allowing a child to either recline or sit, but these need not be detailed since the three-wheeler became all but obsolete before the 'eighties, the four-wheeler taking its place. The inventions as regards variation since then it is unnecessary to mention in this short summary.

It might be said, however, that there have been several patents for converting a carriage into a push-car and for using the body as a bath, cradle, trolley and swing boat, and as recently as 1921 there was a patent for converting a garden roller into a child's carriage ; further, one inventor, in 1886, by working a screw, was able to alter the body lengthwise, and in 1914 Smallwood applied two wheels to a wicker chair in such a manner that these could be housed under its seat, and in 1920 the idea of converting a bedstead into a bath-chair was patented. About the same time there was introduced a car which would so fold that it could be placed in a golf bag, and there is about to be put on the market a folding car which weighs only 16lb.

INVALID CARRIAGES.—The first invalid carriage was patented by Sir John Christopher Van Berg in 1636, and his specification deals with dozens of other articles, none of which are described. Next we come to that of Burton, in 1853, and it was for a three-wheeler with a long handle for obtaining better leverage when raising or turning the front. Metcalfe, in 1854, made a chair for invalids with wheels affixed, which could be folded. In 1895 G. G. Rawl made a carriage which could be used in the house as a carrying chair, and two years later R. Gibbs applied a handle and gearing for propulsion purposes. In 1899 Roberts and Smith produced a carriage, with two wheels, which could be wheeled up or downstairs as well as on the level. N. A. Sawyer, in 1900, patented a carriage propelled by two handles with a chain drive, and Schmidt in 1903 applied an electric motor. Leg rests were patented by Foot in 1904, and in 1907 Maudsley gave us a bath-chair which could be shut up to form a box. In 1912 L. M. Murdoch made an up and down stairs carriage. The war is answerable for many inventions in this line, but mostly for use in the field. One of these, by Foot, in 1915, is for propulsion by the patient rising and sitting, and there have been several inventions of nets to keep out insects, for the comfort of invalids. There have been 167 patents taken out for invalid vehicles by 156 inventors.

STEERING.—There have been 34 patents by 31 persons since Schmoock took out the first in 1854. But the public attach no importance to steering devices, so we need not here discuss them.

BODIES.—Did time permit, it would be interesting to describe the various alterations which have been made from time to time in the design of bodies, and in the material used for their production. As to the latter, there were used solid hard wood, soft wood veneered, stamped sheet metal, papier-maché, wicker, cane, reed, wire gauze filled with a composition, etc., and then plywood, in 1909, and since then celluloid has been used for the panels. The latest idea is to make both pram bodies and hoods of a rubber composition, which could be moulded to any shape, and then vulcanised, yet would be pliable in use. We have had as many as 56 patents taken out, and by 49 persons.

LIGHTS.—" Dora " is answerable for an Order that red and white lights must be affixed to prams, but this is never obeyed. The fines which might have been inflicted to date, should the police have cared to act, would, I estimate, pay off our national debt.

MISCELLANEOUS.—Among the novelties patented was a net which could be instantly fixed over the sides of the carriage and thus form a cradle for a second child—this was the only patent in connexion with prams taken out by a woman. G. H. Needham, in 1883, made a folding cot, with wheels, which would pack into a box, in 1884 Oppenheim constructed a portmanteau with openings at the bottom

for two wheels, and with a handle, which could also be used as a go-cart, and in 1891 Outram introduced a mail cart with removable seats, so that it could be used as a parcel carrier. Schaefer patented, in 1903, a baby carriage with a folding seat for the nurse, and in the same year Feld applied to a carriage a feeding bottle receptacle. Kriz, in 1903, folded his pram so that it could be carried in a carpet bag. In 1908, Fleischmann introduced a carriage with a single wheel, the child reclining in a hammock. Several inventors have constructed prams which could readily be converted into sledges, and in 1912 Gordon-Glassford constructed one which folded up inside a travelling trunk.

But my long list of pram patents only partially covers the range of invention, since many designs were merely registered, and for proof, let me say that H. V. Baker, although taking out only 20 patents, registered upwards of 50 designs. Further, scores of new practical ideas were never protected at all by their inventors.

Yet I have said enough to prove that "mewling and puking in the nurse's arms," neither good for the infant nor its nurse, is now unnecessary. Secondly, that the pram has had seven stages, as follows :—

At first a mere board on two wheels, to push or pull ;

Then a simple lattice of wood on four wheels, which could be drawn ;

And then a mere box drawn on four wheels ;

Then a thing of beauty on four wheels, with springs, which, too, was drawn.

And then of wicker body, springless, with handle still in front ;

The sixth stage, a thing on three wheels, pushed from the back.

Last stage of all that ends this eventful history :

A pram on four wheels, to push, artistic, buoyant, inexpensive,

Sans shocks, sans danger, sans everything undesired,

A feast to the eye, a pleasure to child and nurse.

DISCUSSION.

THE CHAIRMAN was sure the meeting had been greatly interested in the paper. As far as he was concerned, and he thought it would be the same with most other people, he had been too busy in connection with present manufacture to have been able to devote very much thought to the past. The general aim of most makers in the trade to-day was to produce a highly artistic and useful carriage, and he would have liked to hear a little more from the author in regard to the great attention that was given to artistic features in the carriages of the present day, because he took it that the main object was to obtain the approval of the Society in classing the industry amongst the artistic trades. Most of what the author had said appeared to be a history of the business in the past, when there were a good many quite useless inventions which had never been adopted. However, they were all full of interest in the history of prams. He hoped the author, before the paper was published, would see his way to put in some brief description of the high-class artistic article makers were so much interested in to-day.

MR. W. LINES wished to correct a little inaccuracy in the paper by saying that the firm of G. and J. Lines, Limited, were the successors to Mr. John Allen of Hackney Road, E., they having bought the business in the year 1888 and carried it on for a considerable time, afterwards transferring the premises to the Caledonian Road, Islington.

THE AUTHOR said he was delighted to have this explanation. He had written many letters to firms, but he had not been able to compel the firms to answer them. His correspondence had run into hundreds of letters. The father of Mr. Lines had received a letter from him asking about the origin of his business, but no reply was obtained, and, therefore, he was scarcely to be blamed for the omission.

MR. G. K. MENZIES said he hoped the meeting would not resent a layman venturing to say a word or two on the matter. Like everyone else in the room he had been much impressed with the great care the author had taken to get up the history of the past ; he had been at immense trouble in that matter for several months. The paper would go out to the world in the Society's *Journal* and he should like very much if Mr. Sewell would add something at the end on the lines the Chairman had suggested, giving some idea of the present state and size of the industry in this country. He himself should like to know something about the number of firms who were manufacturing and the value of their output and so on. He did not know whether that could be done, but it would add very much to the value of the paper. Another point in the paper that interested him particularly was the question of export trade. The author had stated that before the war there was an export trade in perambulators, but that that had been killed by the heavy cost of transport. There were a number of people in the room who could speak with authority on that subject, and it would be very interesting if they could say whether that really was the sole cause of

the decline of the export trade, and, secondly, whether they had any idea of how that trouble could be overcome.

MR. S. DUNKLEY said it was only that day that he had realised the questions he had been asked in a letter from Mr. Sewell, and, therefore, he had to apologise for not having answered them. He knew Mr. Sewell well and he had read his journal every month for the 30 years that he had been in London. The first memory he had of the baby carriage was something made by a village blacksmith. It was like two steel fire-guards put together with a well very much like that of to-day. That was made in Warwickshire, a few miles from Stratford-on-Avon, and he remembered that when his mother had been gleaning and he was being brought home in the baby carriage from the harvest field the corn that had been gleaned was sticking into his face as he sat in the pram. One or two firms had been mentioned, and he himself recollected 40 years ago Lloyds of Liverpool and Morris of Freeman Street, Birmingham. Someone had asked a question about the origin of the name "bassinette." At one time he could remember his firm buying English wicker cradles which were fixed on an undercarriage, but afterwards they bought the French bassinette, because it was closer woven and very much nicer. He wondered whether that was where the name of "bassinette" came from; it was a name used in the workshops, He had remembrance of many firms mentioned in the paper and the reading of them brought back very sentimental memories of the past. Thirty-five years ago he had had the pleasure of working in a factory (Thos. Simmons & Co., London) where a man named Charles Burton was employed, and he should like to know whether that was the man mentioned by the author.

The paper was a very useful one to the trade, and he thanked the reader.

MR. D. STONE also expressed his appreciation of the paper. No doubt many could call to mind the great impetus given to the trade about 1882 when the bassinette was first introduced. In the early days perambulators were considered to be for children of about 2 or 3 years of age, the idea of carrying them being quite out of the question. He could recollect the appearance of the first bassinette; it was really the French bassinette put on to four wheels. The bottom was quite level, the idea of the well not coming along until a year later. There was no doubt that the bassinette, being adapted for carrying young children, gave a tremendous impetus to the trade. He could just call to mind sitting in the old three-wheel perambulator, with three wooden wheels and no hood. That was the earliest type of carriage he could remember in the year 1872-1873. The trade at that time was very small in comparison with what it was now.

THE CHAIRMAN said that everyone recognised the great work the author had done. It was from a thoroughly disinterested motive that he went to work to put the trade on a higher status amongst the artistic trades. He proposed a very hearty vote of thanks to him for what he had done.

THE AUTHOR said very little criticism had been expressed; certainly not to the extent that he wished, as he was very fond of criticism. He did not put the paper forward as any perfect production. The Society did not exist for the purpose of advertising firms' modern productions, but concerned itself with development, and, therefore, he felt himself restricted, and had concerned himself with trying to show the development from the acorn to the oak. There were 200 firms making perambulators and it would have been difficult to have included 200 names in the paper.

MR. G. K. MENZIES said he only wanted general statistics.

THE AUTHOR said that out of the 200 manufacturers, only about 60 were in any large way of business, and of those about 35 firms would make something like 25 to 75 different designs, and it would take three volumes to deal with those. He had been most careful to avoid referring to the particular make of goods of firms. He was greatly indebted to the Chairman for presiding over the meeting. Mr. Seyler was the proprietor of an active and prosperous concern dating back further than any other pram concern in this country. He thanked the Meeting for the kind way in which the address had been received. With regard to more recent matters, he thought he might be doing a service to the trade if he amplified the details. Very likely he should bring out the history of the pram at an early date, and in that would embody what the secretary had suggested.

GENERAL NOTE.

INTERNATIONAL CONGRESS ON ARCHITECTURAL EDUCATION.—The Board of Architectural Education of the Royal Institute of British Architects, announce that the International Congress on Architectural Education will be held in London from Monday, July 28th, to Friday, 1st August, 1924.

ERRATUM.—The name of the successor of Sir George Beilby, LL.D., F.R.S., as Director of Fuel Research was, by a typographical error, incorrectly given in the *Journal* of 3rd August (p. 658); it should have been Mr. C. H. Lander, D.Sc., M.I.Mech.E., A.M.Inst.C.E.

Journal of the Royal Society of Arts.

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FRIDAY, SEPTEMBER 14, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

PROCEEDINGS OF THE SOCIETY.

HOWARD LECTURES.

DEVELOPMENT OF THE STEAM TURBINE.

By Stanley S. Cook, B.A., M.I.N.A., M.I.M. (Parsons Marine Turbine Co.)

Lecture I.—*Delivered April 30th,* 1923.

Synopsis.

Introduction.
The principle of compounding.
Early indications of directions of progress.
Marine development with direct coupled turbines.
The problem of the propeller.
Combination of turbine and reciprocating engine.
The passing of the direct coupled marine turbine.

In a series of lectures delivered here in 1909, Mr. Gerald Stoney traced the development of the steam turbine from the small 10 horse-power turbine, first constructed by the Hon. Charles A. Parsons in 1884, which turbine is now in the South Kensington Museum, in the company of the famous pioneer inventions of Arkwright and Stephenson, to its latest commercial examples of that period in power stations and Atlantic liners. The steam turbine had, at that date, established its claim to superiority over the reciprocating engine in several fields of work, and the lecturer indicated some directions in which progress was being sought, and predicted a wide extension of the field of utility for this prime mover.

This prediction has been abundantly verified. Both in size of unit and in efficiency the steam turbine has out-distanced its early rival the reciprocating engine, and now holds pride of place as a prime mover in the largest power stations and largest ships of the world.

If we enquire into the reasons for this superiority, we find they are partly mechanical, but chiefly physical. A rotary engine, with its continuity of motion, offered advantages in freedom from vibration and uniformity of stress. The turbine possesses these advantages to the full, but far more important is its greater ability to convert into useful work the energy of the steam, almost up to the limit which nature has imposed upon this conversion. This ability arises broadly from the fact that for motion of a piston at the limited velocity of from 10 to 15 feet per second, is substituted motion of the steam itself at velocities of several hundred feet per second. In a turbine, therefore, the steam can be expanded until its pressure is only slightly greater than the vapour pressure of the water available for cooling.

In a turbine, the pressure energy of the expanding steam is first of all converted into kinetic energy. For a small drop in pressure the increase in velocity energy of a lb. of steam is equal to the product of the pressure drop and the specific volume. If, following the lines of the development of the Parsons turbine, we suppose the whole conversion to consist of a series of small descents in pressure, and take the value of the product of pressure drop and specific volume for each, then the sum of all these products gives the total value of the pressure energy which has been converted into work. We have, therefore, an exact expression for the total energy of the steam available for such conversion, viz., $\int vdp$ between the limits of the initial and final pressures. It will be seen that when the specific volume v is large, as it is at low pressures, even a small value of the pressure drop dp may correspond to a large amount of available energy. Expansion of the steam to the fullest possible extent is, therefore, desirable.

Figure 1 is a pressure volume diagram which shews the comparison between a quadruple reciprocating engine and a turbine in this respect. The area ABCDE of the diagram, represents the energy theoretically available in the case of the reciprocating engine between 215 lbs. per

Diagram shewing Energy of Steam that can be utilised in a Steam Turbine as compared with a Reciprocating Engine.

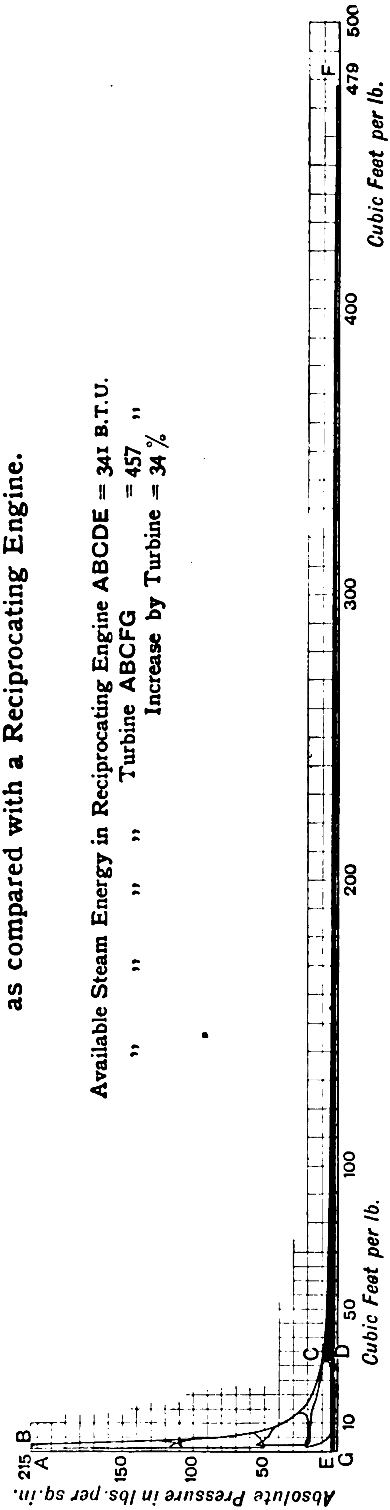

Fig. I

square inch absolute admission pressure, and 24″ Hg. vacuum, with a release pressure of 10 lbs. absolute, and the area ABCFG, the energy available in a turbine working between an admission pressure of 215 lbs. absolute, and a vacuum of 29″ Hg. The expansion in the reciprocating engine cannot be carried further than to about 10 lbs. absolute, since the increase in the size of the low pressure cylinder required would only lead to increased losses by friction, and a small pressure drop is necessary across the exhaust ports to enable the cylinder to be exhausted of its expanded steam during the in-stroke of the piston. In the turbine, on the other hand, the expansion can continue, with the consequent addition to the available energy represented by the shaded area of the diagram. In the case illustrated, this increase is about 34 %.

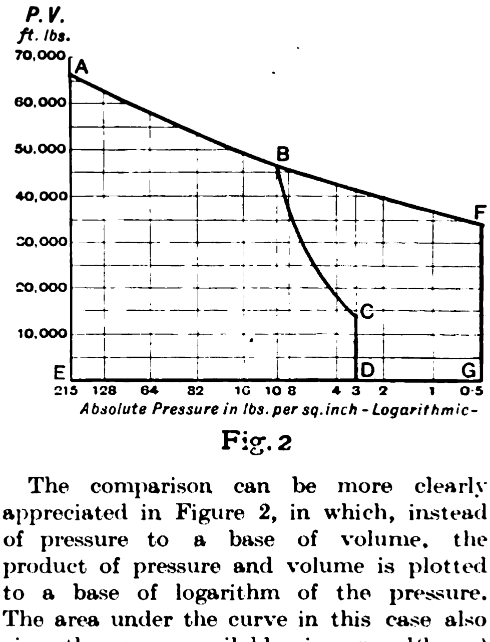

Fig. 2

The comparison can be more clearly appreciated in Figure 2, in which, instead of pressure to a base of volume, the product of pressure and volume is plotted to a base of logarithm of the pressure. The area under the curve in this case also gives the energy available, since $pv. \, d(\log p) = vdp$. In the case of the reciprocating engine, the drop between release and back pressure is represented by a line of constant volume BC. The difference between the two areas shews the increase of energy available for the turbine.

There were evidently great possibilities for the steam turbine, arising out of its power to utilise large expansion ratios. It might be pointed out here, that the same cannot be said for a gas turbine, which would exhaust at a pressure somewhat above atmospheric, so that the comparison between

an internal combustion turbine and an internal combustion engine is not quite the same as between the two types of steam engine.

At the time of the previous lectures, a consumption as low as 13·2 lbs. per K.W. hour, had been realised in turbo-alternators of 5,000 K.W. This is equivalent to about 9½ lbs. per brake horse-power of the turbine shaft, or 8¾ lbs. per indicated horse-power of a reciprocating engine. The best figure realised for a quadruple expansion engine was about 12 lbs. per I.H.P., so that already the turbine had made good for this class of work, the driving of large power-station alternators.

Its application in other fields of work, however, was at that time subject to severe limitations. This was especially so in the field of marine propulsion. The power developed from the steam in the turbine had to be absorbed by a screw propeller working in the water, and the enormous difference in density of the two media, water and steam, imposed different conditions for maximum efficiency. By way of compromise, the turbine was run at a speed considerably below the best for good turbine efficiency, and the propeller at a speed considerably higher than that which gave the best propeller efficiency. This discrepancy was most felt at low speeds, so that the use of the steam turbine for marine propulsion was, at that time, limited to fast vessels, such as war ships, liners and channel steamers. Even in these, the turbines were designed for revolutions far below the most economical, and the propeller revolutions were much higher than they would otherwise have been.

In what is known as the reaction type of steam turbines, the rows of blades alternatively fixed and moving, may be considered as nozzles, the conversion of pressure energy to velocity energy taking place in passage between the blades of each row, whether fixed or moving, producing high velocity jets of steam, the momentum of which is the origin of the turning force of the rotor. With the impulse type of turbine, this conversion of pressure energy to velocity energy takes place only, or chiefly, in the nozzles fixed in the casing, and the high velocity jets thus produced impinge freely upon the moving blades. In either type, the efficiency of the conversion of velocity energy into work on the blades, is conditioned by the "velocity ratio," usually understood as the ratio of the peripheral velocity of the blades to the steam velocity corresponding to the pressure drop.

In order to obtain good efficiency, the velocity ratio must be kept high. Now, the velocity attained by a fluid when forced through an orifice with a given pressure is inversely proportional to the square root of its density; low density, therefore, involves high velocity. With a gaseous fluid like steam, the velocities which would be attained by discharging steam from boiler pressure, through a single orifice or blade passage, is of the order of several thousand feet per second, and too high for efficient utilisation at such peripheral speeds as are mechanically safe.

With the blade speeds attainable in commercial practice, many turbines must be placed in series, the expansion of the steam being divided up between them in order that the steam velocity may be reduced to give an efficient ratio between blade velocity and steam velocity. This is the principle of compounding, the fundamental principle introduced by the Hon. Charles Parsons in his earliest steam turbine.

This principle of compounding, finds a simple expression if we consider the case of a turbine which has a number of similar stages, all with the same velocity ratio. For, if V be the velocity of the steam jet due to the pressure drop at any stage, the energy per pound converted into velocity is $\frac{V^2}{2g}$. The total energy so converted in a whole series of such turbines, is the sum of all these values of $\frac{V^2}{2g}$, or $\sum \frac{V^2}{2g}$, which sum is, therefore, an equivalent expression for the total available energy $\int vdp$.

If the blade speed, u, is always proportional to the steam speed, V, to maintain a constant velocity ratio, with a given value of $\sum V^2$, we must have a given value of $\sum u^2$, in other words, for a constant velocity ratio of the whole turbine, $\sum u^2$, or what amounts to the same thing, $\sum d^2R^2$, d being the diameter and R the revolutions, must be proportional to the total available energy. This is the origin of the Parsons blade co-efficient K, which is merely the sum of the values d^2R^2 for all the pairs of rows in the turbine. For given steam conditions, since efficiency is a function of velocity ratio, K becomes a criterion of the average blade efficiency of the whole turbine.

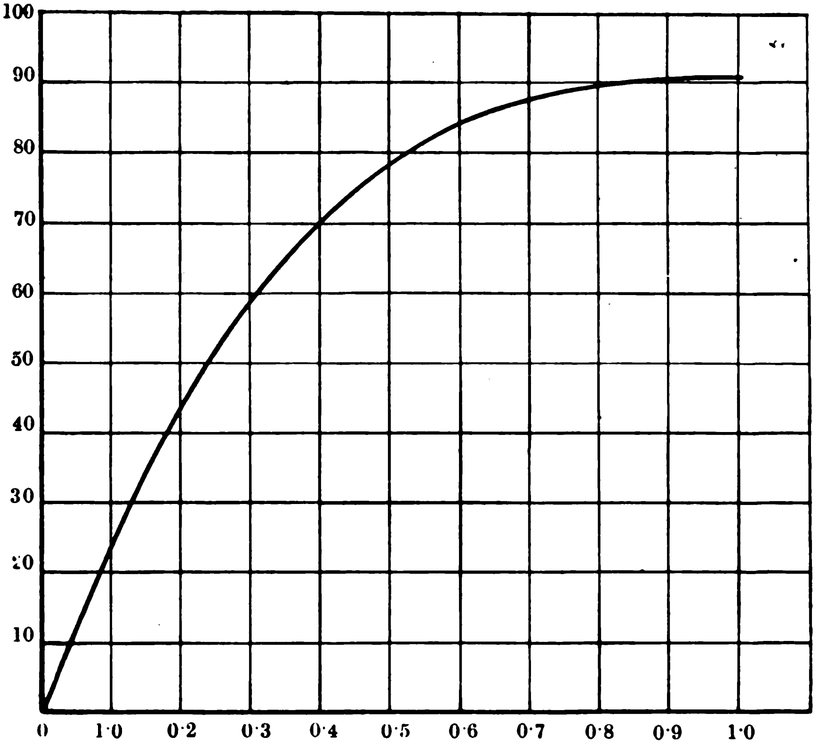

FIG. 3.

Inherent Efficiency of Parsons Reaction Blading.

"Velocity-Ratio" $= \frac{\text{mean blade velocity.}}{\text{steam jet velocity.}}$

It was, therefore, in the increase of the value of $\sum u^2$, either by increasing the number of rows or stages, or by increased peripheral velocities, that higher efficiencies of conversion were to be attained up to the point of maximum blade efficiency. What this maximum efficiency is, was a matter of experiment, but in well designed reaction blades, it is not far short of the maximum efficiency obtained in well shaped nozzles. Figure 3 gives a curve shewing the variation of efficiency with velocity ratio, as obtained by recent experiments.

This is the principal factor governing turbine efficiency, and determining the proportion of the energy of the steam that can be converted into work on the blades. A few losses have to be deducted; loss by leakage over the tips of the blades, in the case of reaction turbines, and in the case of impulse turbines, leakage at the glands of the diaphragms which separate the stages, windage of the idle blades, and skin friction of the discs; loss by leakage at the end glands, and friction of bearings and adjusting blocks, complete the tale of losses. The designer's objective must be so to proportion the turbine as to reduce these losses to a minimum, and it will readily be seen that the larger the capacity of a turbine, the smaller will be the total percentage of loss arising from these causes.

Concurrently with increase of blade efficiency, the energy of the steam available for conversion could be increased by increasing the range of expansion, using higher boiler pressures and higher vacua in the condenser, and by superheating the steam. These all lead to an increase in the value of $\int vdp$, the superheat increasing the volume of the steam. (The value of K must be still further increased to correspond with this increase of $\int vdp$, if the blade efficiency is to be maintained.) It is true that to obtain this greater available energy, by superheating, at any rate, a larger quantity of heat must be given to the steam in the boiler, but in general, a gain in overall thermal efficiency results, exemplifying Carnot's principle that heat should be supplied at the highest possible temperature, and rejected at the lowest.

The avenues of progress open to the steam turbine were thus clearly marked out :—

(1) A progressive increase in the size and capacity of a single unit, to meet whatever demand there might be for large units, a demand which was then actually arising from the development of large central power stations in many countries,

and from the increase in the displacement and power of naval and commercial ships, both of which developments were materially encouraged by the recognised possibilities of the steam turbine in this direction. (2) An improvement in economy by extending the range of expansion of the steam to its utmost limits, and by an increased use of compounding to give the turbine its highest efficiency; and (3) the invasion of fresh fields of work, by the adoption of some form of gearing to remove the limitations which those fields otherwise imposed upon the speed, and, therefore, upon the efficiency, of the turbine.

All marine turbines building to-day are connected to their propeller through some form of gearing, the introduction of which marked a real revolution in turbine practice. I propose, however, in this first lecture, to review on broad lines the progress of the direct coupled marine turbine, prior to the advent of gearing.

In the pioneer turbine vessel, the Turbinia, three turbines were fitted, one on each of the three shafts, a high pressure, an intermediate pressure, and a low pressure turbine. The principle of compounding referred to above indicates that the arrangement of the turbines in series leads to the highest efficiency, with a given weight of turbines. On the other hand, there are practical considerations, such as facility of manœuvring, which led in many cases to a violation of this principle, with the consequence that we find instances of almost every possible variety of arrangement of turbines on the propeller shafts. With three shafts, the arrangement most commonly adopted consisted of a high pressure turbine on the centre shaft, and two low pressure turbines on the wing shafts. Astern turbines were incorporated in the low pressure exhaust casings, and these low pressure turbines were operated as independent units for manœuvring, the high pressure turbine being automatically put under vacuum when steam was admitted to the low pressure turbines.

In four shaft vessels, the turbines were first of all arranged in two compound units of high pressure and low pressure turbines, one on each side of the vessel. This was the arrangement adopted in the Lusitania and

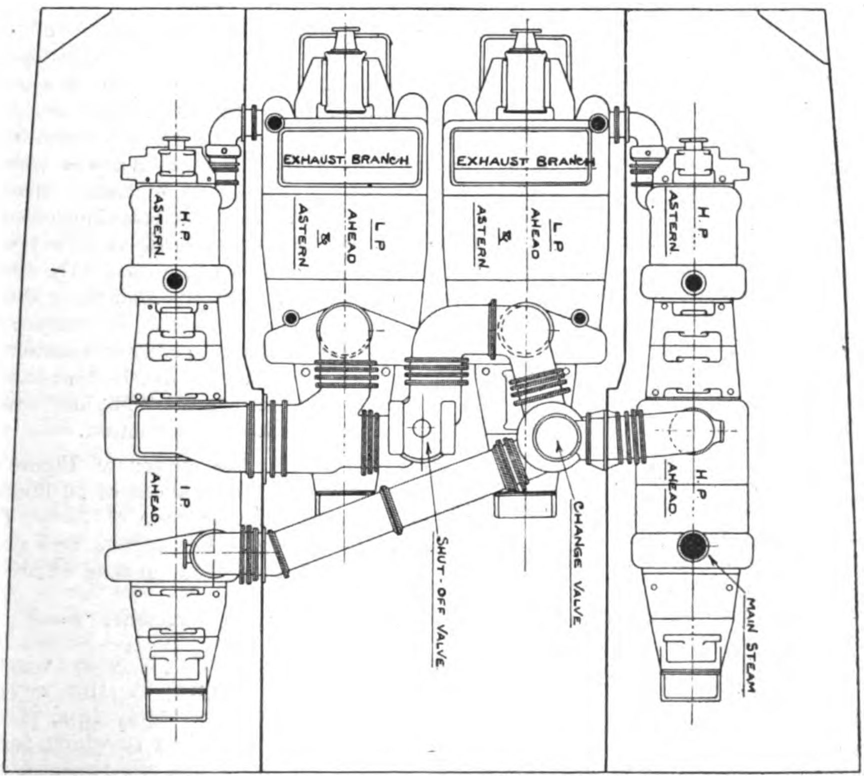

Fig. 4. Q.S.S.S. Aquitania. Arrangement of Turbines.

Mauretania, but later, with increased experience of large turbines, the arrangement adopted for the Imperator and Aquitania was that known as the four shaft triple system, consisting in the case of the latter, of high pressure and intermediate pressure turbines on the wing shaft, and two low pressure turbines in parallel on the inner shafts. This arrangement, which is illustrated in Figure 4, led to a distinct improvement in efficiency, and some saving in weight. Special manœuvring valves, however, were necessary, in order to separate the high pressure and intermediate pressure turbines, when it was desired to work the port and starboard engines independently.

The Aquitania's turbines developed a power equivalent to 60,000 I.H.P. at 155 revolutions per minute. Some idea of the enormous size of these turbines will be gathered from a statement of their weights. The total weight of the H.P. turbine was 240 tons, the rotor itself weighing 80 tons. The total weight of each of the L.P. turbines was 445 tons. The L.P. rotor drum was 12 feet in diameter, and the weight of the complete rotor 140 tons. The astern turbines consisted of separate high pressure turbines on the outer shafts, and low pressure turbines on an extension of the low pressure ahead rotor. The total weight of all the turbines was over 1,600 tons.

In destroyers and cruisers, the same conflict between the conditions which made for economy, and those which gave facility for manœuvring led to the adoption of two shafts in preference to three, and an independent unit on each shaft. Under these conditions, the efficiency realised was determined by the question of the maximum value of K or $\sum d^2R^2$, that could be provided on a given weight, and in a given space. It was at this point that impulse wheels were introduced for marine turbines. With single turbines at low revolutions, the maintenance of a large enough value of $\sum d^2R^2$ for efficiency involved either prohibitive length, or large diameter of rotor, with short initial blades and heavy loss by leakage over the blade tips. These independent turbines were, therefore, designed with an impulse wheel at the high pressure end and partial admission. Since with impulse blading the pressure drop is confined to the fixed nozzles, these nozzles could be made to extend over only a small portion of the circumference. High initial pressure could thus be maintained. This arrangement had a further advantage in enabling low speed cruising conditions to be met, for which the admission belt could be subdivided to any required extent, special control valves being provided on the nozzle boxes for the purpose. This type of turbine with a single impulse wheel is generally referred to as the impulse-reaction type. In other vessels of the same class, the impulse type of blading was adopted still more [illegible]ly, the high pressure portion of the turbines consisting of a series of impulse wheels separated by diaphragms. Such a design was first adopted in this country by Messrs. John Brown & Co., Clydebank, in the turbines of H.M. Cruiser Bristol.

For marine work, the problem of the turbine was entangled with that of the propeller. The overall efficiency is composed of two factors, the efficiency of the turbine which increases with the speed, and the efficiency of the propeller, usually decreasing with the speed. For a given speed of vessel, and a given propulsive horse-power, the relation between propeller efficiency and revolutions is, therefore, an important part of the problem.

In Figure 5, are curves of efficiency to revolutions for a screw developing 5,000 propulsive horse-power at a speed of 20 knots. It is presumed that corresponding to each point on these curves, the pitch ratio, surface ratio, etc., are so chosen as to give the maximum efficiency that can be obtained at that particular speed of revolution, because otherwise it would obviously be possible to improve the combined efficiency by merely modifying the characteristics of the screw. The choice of these characteristics is merely a question of propeller design, for which the experiments of "Froude" and "Taylor" furnish a ground-work of information.

Although the curves of Figure 5 have been plotted for a speed of 20 knots, and a propulsive horse-power of 5,000, they are applicable to other speeds and powers, if we use for abscissa, instead of revolutions, a revolutions co-efficient, $k = R\sqrt{\frac{\text{E.H.P.}}{V^5}}$ E.H.P. denoting the propulsive horse power, V the speed and R the revolutions. This follows immediately from the law of comparison, according to which, for similar stream line motions, the pressure per unit area varies as the square of the speed. For

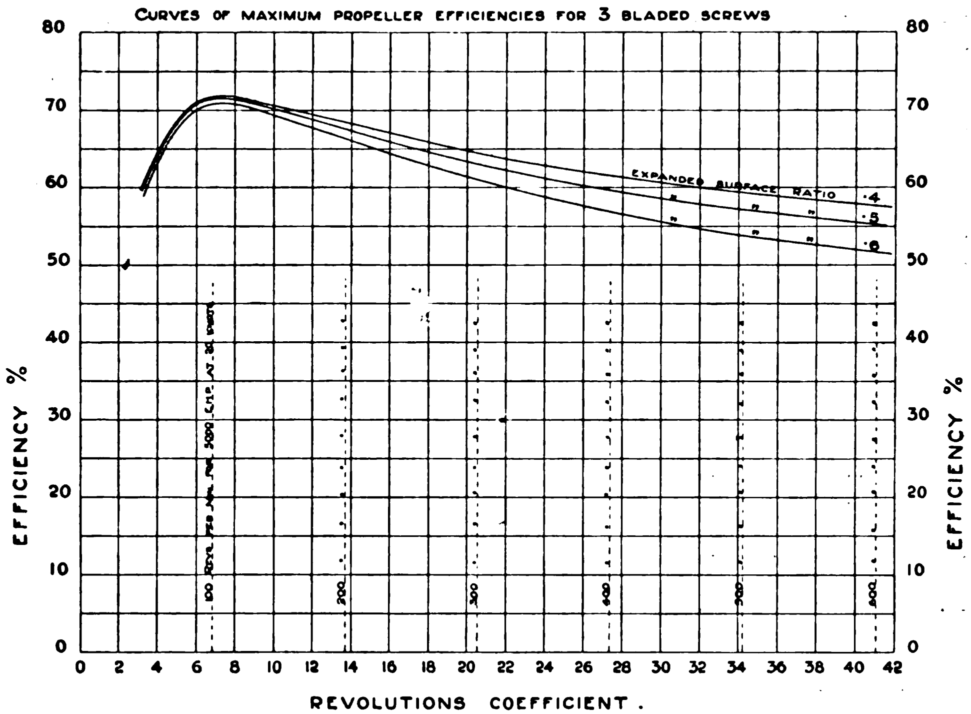

FIG. 5.

screws of similar proportions, with the same slip ratio, the total thrust varies as the square of the diameter and the square of the tip speed, and, therefore, as the 4th power of the tip speed, and inversely, as the square of the revolutions; so that, for similar screws, working under the same conditions of slip and efficiency, the horse power varies as the 5th power of the speed, and inversely as the square of the revolutions.

From these curves, the difficulty in adopting turbine propulsion to vessels of low speed can be appreciated. The revolutions for similar screws, that is, for screws of similar efficiency, vary as the square root of the fifth power of the speed. For instance, for a vessel of ten knots, and 3,000 H.P. revolutions as low as 100 per minute, allow only of a moderate propeller efficiency.

The two co-efficients, viz., the velocity ratio co-efficient for the turbines and the revolutions co-efficient of the propeller, are thus fundamental to the design, and should be chosen at such values that the loss of turbine efficiency by a decrease in revolutions is equal to the gain of propeller efficiency. The speed of rotation will then be such as to give the best combined result for the turbine and propeller chosen.

The position is best illustrated by an example. In the first mercantile steamer, the King Edward, as originally designed, the turbines and propellers ran at an average speed of 820, and the revolutions co-efficient was 25, which, as will be seen, is low down on the efficiency curve. The turbines had a K value of 76, or a velocity ratio of ·4, again low down on the turbine efficiency curve. But for the propeller, the turbines might have been designed at higher revolutions with a K value of 300, and average velocity ratio ·8, and, but for the turbines, the propellers might have been run at 400 revolutions, with the revolutions co-efficient value of 12. There was then, a sacrifice of more than 30 per cent. in turbine efficiency, and of about 15 per cent. in propeller efficiency, or a total loss of efficiency of about 50 per cent. The revolutions were subsequently reduced by fitting larger propellers, but the improvement in propeller efficiency so obtained was just about equalled by the reduction in turbine efficiency. This loss was a heavy handicap, and yet, in spite of it, the King Edward was, and continues to be, a very successful steamer, so great are the advantages of the turbine.

The development of the turbine, sub sequent to the King Edward, was marked

by a steady increase in the K value, of which Table I. gives a few examples. The revolutions co-efficient was also diminished. Both the increase in K and the decrease in propeller revolutions involved increase of weight of turbines, and improvement in efficiency by this means was carried as far as the conditions of weight and space available with direct driving turbines allowed.

TABLE I.

	K	k
King Edward	76	25
Onward	83	23
Viking	71	18·5
Carmania	90·5	18·4
Mauretania	85·5	12·0
Aquitania	122	12·85
H. M.S. Dreadnought ..	79·5	18·8
,, King George V.	111·75	21·5
,, Indefatigable	100	14·7
,, Lion	110	13·9

The difficulties of the propeller were increased by the phenomenon of cavitation, which was encountered in propellers of high tip speed and high slip ratio. The propeller blade moves through the water edge first, but at a slight angle. The motion of the wing of an aeroplane has now made everyone familiar with a motion of this kind. But in water, as the angle is increased, or as the speed is increased, a condition is reached in which the stream lines can no longer follow the back of the propeller blade, so that a vacuous space is formed there. This results in a reduction of the normal thrust. In order to keep the thrust per square inch of the blade surface below the value at which cavitation begins, the surface of the blades was made a large proportion of the disc area. Thus small diameter and large surface ratio became characteristic features of propellers for direct driving turbines, so much so, that a practised eye could at once distinguish a screw that was destined for a turbine drive. In the case of the first turbine liners, serious doubts were at first expressed as to the ability of the screws, which, in place behind the ship, appeared quite insignificant, to propel the vessels across the Atlantic, but the principles on which their proportions were designed were fully vindicated.

The first effort to break down the barrier imposed by low propeller revolutions was the introduction of a combination of a compound or triple expansion reciprocating engine, with a low speed turbine, this reciprocating engine exhausting into the turbine at a pressure slightly higher than the usual release pressure of an L.P. cylinder.

Some weight was thus saved in the reciprocating engine, and the turbine carried on the expansion of the steam down to a high vacuum—considerable improvement in economy was obtained in this way in low speed ships, for which hitherto only a reciprocating engine drive had been adopted. The turbine was coupled to its own propeller, usually of small diameter, and even here there was a limitation, and some sacrifice had to be made of both turbine and propeller efficiency. The addition of this low pressure turbine gave an improvement in efficiency of 12 to 14 per cent.

Apart from the combination designs, there have been comparatively few direct driving turbines applied to vessels below a speed of 18 knots. A few steam yachts were turbine driven. In these, freedom from vibration and economy of general maintenance were considered of more importance, but, as regards efficiency, the best that could be said of them was that they compared well with reciprocating engines.

An example of the combined installation in the S.S. Otaki, built by Messrs. Denny Bros., of Dumbarton, was referred to in the Cantor lectures of 1909, and the installation and results for this vessel are described in a paper by Commander Wisnom, read before the Institution of Engineers and Shipbuilders in Scotland in 1909.

This line of progress was followed up in later vessels, the most notable examples being the White Star liners, including the Laurentic, Titanic, Olympic, and Britannic.

In the case of the Laurentic, a close comparison was made between its performance and that of a sister vessel, the Megantic, fitted with quadruple expansion reciprocating engines. The coal consumption was 14 per cent. less, and the vessel was 3/4 knot faster for the same boiler power. The low pressure turbine was fitted to drive the centre shaft, receiving exhaust steam from two reciprocating engines. The turbines of these combination designs were of huge dimensions, probably the largest marine turbines ever built. For example, the Britannic's rotor was

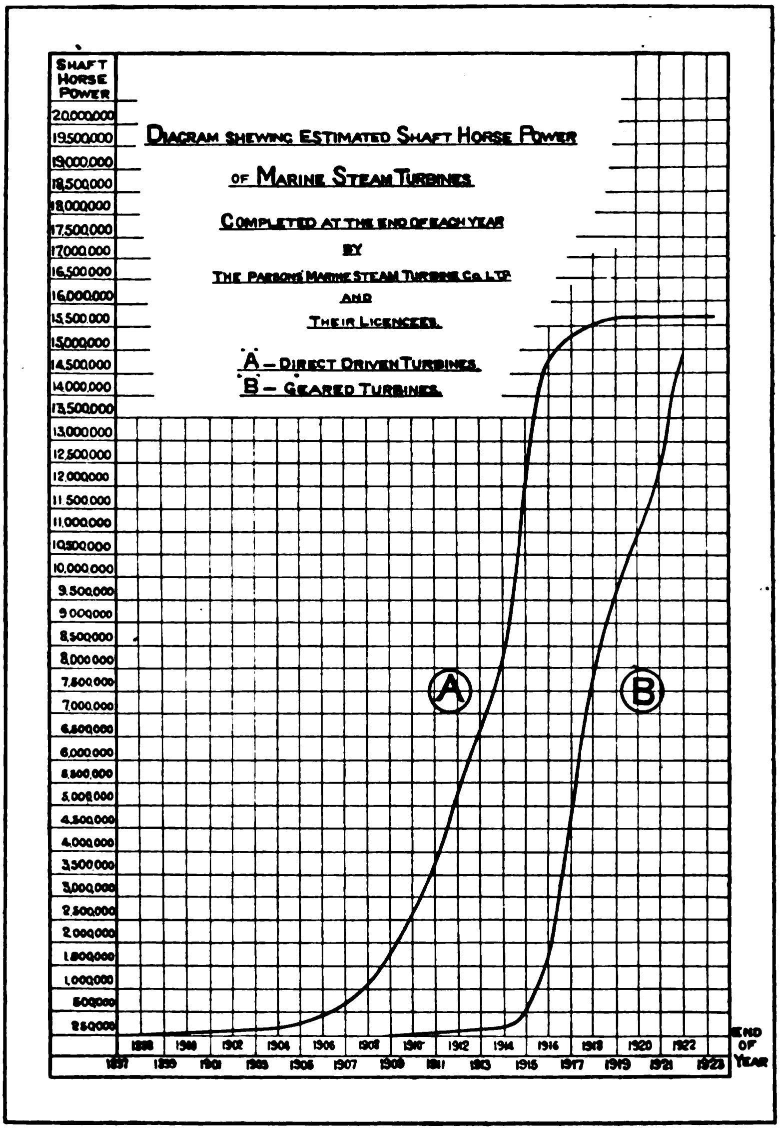

Fig. 6.

12ft 6in. diameter, and weighed 150 tons, whilst the weight of the complete turbine was 500 tons. The overall length of the turbine was 50 feet. It developed 18,000 S.H.P., out of a total of 46,000.

The direct driving turbine for marine work reached its zenith in the turbines of the famous battle cruisers, which were the mainstay of our defence against Germany in the Great War. With very few exceptions, all the vessels of that formidable fleet which we had gathered in the North Sea were turbine driven, and their maintenance in constant commission in the face of the enemy for four years, sweeping the sea with unceasing vigilance, is in itself a monument alike to the steam turbine and to the skill of our naval engineers.

The turbines of H.M. Battle Cruiser Lion, and of her sister ship the Princess Royal, both built by Messrs. Vickers, Ltd., at Barrow-in-Furness, developed a total power of 70,000 S.H.P., in a compound arrangement on four shafts, with an astern turbine on each shaft, an arrangement, in fact, generally adopted in British warships, from the Dreadnought onwards. The consumption of these turbines was $11\frac{3}{4}$ lbs.

per S.H.P. The extent to which compounding was carried in order to realise this consumption, is indicated by the value of the velocity ratio co-efficient K, which for these turbines was 110.

The huge turbines of these battle cruisers, of the Aquitania and Britannic and sister vessels may be said to have marked the passing of the direct turbine, but before it passed, it had reached a total output, the magnitude of which this brief outline is quite inadequate to convey.

In Figure 6, curve "A" shews the growth of the output of direct coupled marine turbines. At the lower part of the curve, we witness the struggles of the early years of their development, followed by a rapid rise after experience had given confidence. Curve "B" is a similar curve for the geared turbine. It is interesting to note how the upper curve suddenly stops when the geared turbine drive, having run with similar caution through its probationary years, was ready to carry on the record.

Modern civilisation depends largely upon the production of power which only began to be developed less than two centuries ago by Newcomen and Watt. We have in this diagram, concentrated in a few lines, the history of an epoch-making revolution, by Parsons, in the means of production of power, a record of its growth to the enormous output of 15,700,000 S.H.P. in marine propulsion, and its complete displacement, as though by a counter-revolution, by the geared turbine; both revolution and counter-revolution being the product of the genius and energy of the same inventor.

I propose, in the next lecture, to deal with the introduction of gearing, by which the difficulties arising from the conjunction of a high speed engine with a low speed propeller, were finally removed, and which immediately led to an enormous leap upward in marine turbine efficiencies.

NOTES ON BOOKS.

Redwood and Eastlake's Petroleum Technologist's Pocket-Book. Revised by Arthur W. Eastlake. London: Charles Griffin & Co., Ltd. 1923. 15s. net.

By friendly co-operation many who are prominent in connexion with petroleum have produced an exceptionally satisfactory compact book of reference; the more important matters being presented in minute detail, while others are touched on more lightly. Besides xxiv + 544 pages of letter-press, the work before us includes a miniature atlas, which is carried in a pocket inside the back cover; the atlas comprising eight good maps (Bartholomew's) on which all known petroleum deposits are indicated by signs in red; one form for worked deposits and another for unworked. The map of the earth on Mercator's projection has special interest as indicating at a glance the general grouping of all known deposits, and, if our imagination may be allowed to drift through the distortions incidental to Mercator's projection, also to bring the eastern and western continents into that state of union which perhaps existed ages ago. The main grouping appears to be suggestive of an original area of intense vegetable growth across Herschel's "terrestrial hemisphere." (See Herschel's "Astronomy" 1865 ed. p. 186.) A coloured geological chart, which forms the frontispiece, may be regarded as more or less supplementary to the atlas, and indicates the usually accepted order of the stratified formations, while the geological section of the Pocket-Book (pp. 59-91), is remarkable for its carefully selected hints, facts, and instructions calculated to explain the conditions under which petroleum is found, and to assist the prospector in finding, identifying and reporting. Messrs. Griffin's most recent addition to their series of works on petroleum—a series headed by the exhaustive Redwood Treatise in three large volumes with a total of over 1,300 pages—is suited to the needs of all who require a concise book of reference, and the prospector may safely take it on tour as his sole reference book. He will find a reminder list (pp. 23-25) of appliances to be taken, and details as to chemical and physical examination, together with everything essential in making a provisional report from the field; output and qualities from the more important sources being so given as to enable the prospector to include all the comparative data which can be looked for in a report from the field.

Part VII., which treats of weights and measures (pp. 345-397) is notably pertinent to the aims of the book, as including particulars of various standards which linger in about a score of countries which have partly or nominally adopted the metric system, and in the case of important conversions such as poods and tons, versts and miles, or desiatines and acres, full conversion tables almost of the ready-reckoner type are given, but, in addition to such tabular facilities, there is a comprehensive list of multiplication factors for conversion. The exceptional completeness of this section is shown by the half page devoted to the "miners' inch" (water flow through an inch-square opening), and such articles of the calendar as may bear on operations in Russia or in Mohammedan countries.

Claim-making and other legal or official procedures are well and sufficiently considered.

The index is admirable, and has shown well against all our tests, but the title is not quite ideal as it does not catalogue well, is over long and it gives

no ready phrase for a shopman, a purchaser, or a librarian. A shorter title may be desirable in view of the probability of many editions.

BRITISH ASSOCIATION.

The ninety-first annual meeting of the British Association for the Advancement of Science was opened at Liverpool on September 12th, under the presidency of Professor Sir Ernest Rutherford, F.R.S., the subject of his inaugural address being "The Electrical Structure of Matter." In the course of the discourse he referred to the important question of the energy relations involved in the formation and disintegration of atomic nuclei first opened up by the study of radioactivity.

"For example, it is well known that the total evolution of energy during the complete disintegration of one gramme of radium is many millions of times greater than in the complete combustion of an equal weight of coal. It is known that this energy is initially mostly emitted in the kinetic form of swift α and β particles, and the energy of motion of these bodies is ultimately converted into heat when they are stopped by matter. Since it is believed that the radioactive elements were analogous in structure to the ordinary inactive elements the idea naturally arose that the atoms of all the elements contained a similar concentration of energy, which would be available for use if only some simple method could be discovered of promoting and controlling their disintegration. This possibility of obtaining new and cheap sources of energy for practical purposes was naturally an alluring prospect to the lay and scientific man alike. It is quite true that, if we were able to hasten the radioactive processes in uranium and thorium so that the whole cycle of their disintegration could be confined to a few days instead of being spread over thousands of millions of years, these elements would provide very convenient sources of energy on a sufficient scale to be of considerable practical importance. Unfortunately, although many experiments have been tried, there is no evidence that the rate of disintegration of these elements can be altered in the slightest degree by the most powerful laboratory agencies. With increase in our knowledge of atomic structure there has been a gradual change of our point of view on this important question, and there is by no means the same certainty to-day as a decade ago that the atoms of an element contain hidden stores of energy."

He discussed the reasons for this change in outlook and in concluding his survey of the great period of advance in physical science covered by him, he said :—

"In these great additions to our knowledge of the structure of matter every civilised nation has taken an active part, but we may be justly proud that this country has made many fundamental contributions. With this country I must properly include our Dominions overseas, for they have not been behindhand in their contributions to this new knowledge. It is, I am sure, a matter of pride to this country that the scientific men of our Dominions have been responsible for some of the most fundamental discoveries of this epoch, particularly in radioactivity.

"This tide of advance was continuous from 1896, but there was an inevitable slackening during the War. It is a matter of good omen that, in the last few years, the old rate of progress has not only been maintained but even intensified, and there appears to be no obvious sign that this period of great advances has come to an end. There has never been a time when the enthusiasm of the scientific workers was greater, or when there was a more hopeful feeling that great advances were imminent. This feeling is no doubt in part due to the great improvement during this epoch of the technical methods of attack, for problems that at one time seemed unattackable are now seen to be likely to fall before the new methods. In the main, the epoch under consideration has been an age of experiment, where the experimenter has been the pioneer in the attack on new problems. At the same time, it has been also an age of bold ideas in theory, as the Quantum Theory and the Theory of Relativity so well illustrate."

The intellectual interest due to the rapid growth of science to-day could not fail to act as a stimulus to young men to join in scientific investigation. But in order to obtain the best results our universities and other specific institutions should be liberally supported and there must be a reasonable competence for those who have shown a capacity for investigation.

EXPORT TIMBERS OF THE PHILIPPINES.

According to a report by the Director of Forestry at Manila on the export timbers of the Philippines, the more plentiful woods suitable for export are included very largely in two botanical families, *Leguminosae* or locust family, and *Dipterocarpaceae* or lauan family, of which the first furnishes the harder and more highly coloured and figured woods and the latter the larger volume, making up 75 per cent. of the total volume of commercial woods of the Philippines. While not having such striking grain and colour or being generally quite so hard and durable as the leguminous species, the dipterocarps have a very pleasing colour and grain, somewhat resembling mahogany, for which they are substituted in the American market under the name of Philippine mahogany.

In point of quantity the total cut for 1921 for the principal leguminous species was some 10,000,000 board feet, while the dipterocarp or lauan species amounted to over 80,000,000 board feet. With the large local demand and proportionately high prices of the leguminous species for both construction and cabinet purposes, there will probably never be any appreciable export trade in these woods, but the large quantities of the lauan group

available and the fine finish which can be secured with them for cabinet-work and interior finish make possible the development of a large export trade.

During 1921 the total exports of the lauan group (red and white lauan and tanguile) were 9,870,000 board feet out of a total export volume of 11,790,000 board feet, and a similar proportion in 1920 of 12,420,000 board feet of lauans out of a total of 13,860,000 board feet of all species. Of the remaining quantity of export timber indicated in these figures, the major portion is composed of the heavier members of the dipterocarp family, such as apitong, guijo, and yacal; the nondipterocarp species for 1921 amounting to only 145,000 board feet.

The cigar-box wood *par excellence* of the world has for many years been the Spanish cedar of tropical America. Kalantas is closely related to, and, to all practical intents, identical with Spanish cedar, the marked similarity in colour, texture, and odour, rendering the two varieties almost indistinguishable. It is the only native wood used in Manila for high-grade cigar boxes. For cheaper boxes several of the lauans and nato are used.

AUSTRALIAN GYPSUM INDUSTRY.

Gypsum is found in various parts of the Commonwealth of Australia, but is at present mostly worked in Victoria and South Australia, although the Hay, Hillston, and Mossgiel districts of New South Wales have also given good results, and very large deposits have been found near Lake Austin and Lake Seabrook in Western Australia. The production of Victorian gypsum in 1920 amounted to 3,393 tons, valued at £1,696, chiefly from Lake Boga, while 40,000 tons, valued at £32,000, were obtained in the same year from southern Yorke Peninsula in South Australia. A factory for the manufacture of plaster of Paris has been erected at Dry Bone Lake, South Australia, but it is said that there is room for other factories of this kind to meet the present and future demand.

According to a report by the United States Trade Commissioner at Melbourne, Australian gypsum occurs in two forms—large crystals, and a floury earth consisting of minute crystals, known as "copi." It is used largely as a natural manure, especially for light moist soils, and recent experiments at Goroke, Victoria, have given wonderful results in wheat growing. A dressing of 1.5 tons an acre applied with 1 hundredweight of superphosphates increased the yield by 20.9 bushels an acre, as compared with the crop grown without manure. Superphosphate by itself increased the yield on another plot by 9.8 bushels per acre, so that the effect of the gypsum was to increase the yield by 11.1 bushels per acre. The chief difficulty in the way of the extensive use of gypsum for fertilising is the price, which, at £2 5s. per ton, is considered too high for more than experimental work. However, with such large and easily procurable deposits, the expansion of the Australian industry would seem to be only a matter of time.

Thus far, gypsum has been little used in the Australian building trade. Gypsum hollow tiles and blocks are very seldom in demand. Concrete is more popular, but many builders consider gypsum superior to concrete on account of its being waterproof.

PHOSPHATE DEPOSITS ON RED SEA COAST OF EGYPT.

Although phosphate deposits have been discovered at many points in Egypt, writes the United States Consul at Port Said, those along the Egyptian coast of the Red Sea are the only ones of present-day commercial importance. The deposits at Koseir, El Karn, El Hamama, El Sibaia, and Sofaga are known to be valuable. The last named (Sofaga, 18 miles from the coast) is being developed at present by an English company; the deposit is said to contain over 58 per cent. of tricalcate phosphate and to be of high value as a fertiliser. The mine, which employs at present about 2,000 workmen, ships its product to the coast by means of an electric railway, and practically all of the product is being exported to Japan. Japanese and English steamers, having delivered oriental cargoes in European ports, return and pass through the Suez Canal in ballast, with a saving of 2.50 francs per net ton in canal tolls, and load phosphate at Sofaga for Japanese ports. The annual production is about 125,000 tons.

The deposits at Koseir and El Sibaia are being exploited by an Italian company, which exports the product to Italy. Phosphate cargoes shipped northward through the canal from this source amounted to 28,000 tons in 1919, 69,000 tons in 1920, and 35,000 tons in 1921.

SILK INDUSTRY OF SYRIA.

The rearing of silk worms has always been a very important industry in certain parts of Syria, writes H.M. Consul-General at Beyrout in his recent report, but it is now suffering severely owing to the destruction of a great part of the mulberry trees which in the past were so extensively cultivated, chiefly in the Lebanon, but also in the coastal districts and round Antioch. Another adverse factor is the lack of expert labour. This work was executed in the past by young girls, who have, since the war, grown up, emigrated or disappeared. The present labour employed is insufficient, undisciplined and altogether unsatisfactory. The indigenous breed of silk worms has entirely ceased, exterminated by disease, and its place has been taken by a foreign kind, produced from eggs imported chiefly from France. The eggs begin to hatch about the latter part of April in the plains

and 20 days later on the hill slopes, the cocoons being produced in from 33 to 40 days. There is only one kind of cocoon and silk grown in the country, but the quality naturally varies according to the amount of care and labour bestowed on the rearing of the silk worm, for, when properly raised and fed, it produces a full cocoon, from which a good quality of silk is obtained. The production of silk cocoons for 1922 was approximately 2,680,000 kilos or one-third of the pre-war production.

The spinning industry is also centred in the Lebanon and in pre-war days there were no fewer than 152 factories, with a total of 8,560 pans (Bassines) scattered over different parts of the mountain, but here again, the war has affected this industry very seriously and to-day there are only approximately 50 factories with a total of 2,000 pans working, owing chiefly to lack of capital and insufficient experienced labour. All silk of better quality is normally exported either as raw silk or as dried cocoons. What is rejected goes to the native looms, supplemented by Chinese silk.

NEW SOURCES OF PULP.

In view of the approaching world shortage of pulp timber, says *The Times Trade and Engineering Supplement*, British attention turns naturally to other sources of papermaking material within the Empire. The three main types are Canadian straw crops, bamboo and the native grasses of India. Paper has been made from straw for a considerable time past, principally in Germany and Austria, in which countries it takes the same place as esparto grass occupies in Great Britain. Efforts have been made by our home mills to turn the straw crop to good account, but with indifferent success, owing to the high cost of collection and greater facility for handling the cheaper esparto or woodpulp. All told, the straw crop of Great Britain constitutes a low tonnage figure. In Canada there are about 50 million acres of land carrying crops, the yield of which, apart from the grain, is at present sheer waste product. With careful treatment, it is easily possible to secure a 30 per cent. yield of papermaking fibre from an average straw crop. The most difficult problem is that of collection and transportation, but it is possible that in the normal course of development and opening of the country, some of these difficulties would be automatically solved. At least, there is an interesting proposition which can be entertained within the Empire, whenever real necessity makes utilisation of further sources of papermaking material imperative.

In India the several native mills have long been producing excellent grades of paper from bamboo and several sorts of grasses. The supply of these materials is illimitable. They have been tested here and proved equal to esparto and woodpulp. Whether the difficulty and expense of treatment and transportation in the form of bales of half-stuff is overcome or not, one thing is tolerably certain, namely, that India will continue to develop her own resources and will ultimately satisfy the bulk of her paper demand.

VEGETABLE OIL PRODUCTION IN THE NETHERLANDS.

The vegetable oil industry of the Netherlands comprises a total of 67 mills, employing an aggregate of about 5,000 workmen. This industry centres largely in the so-called Zaan district near Amsterdam, and in Rotterdam and Amsterdam. These mills work linseed, rapeseed, sesame seed, soya beans, peanuts, and copra, and a large proportion of the mills produce both cattle cakes and meal.

According to a report furnished by the United States Commercial Attaché at the Hague, the total estimated production of vegetable oil in the Netherlands declined from about 113,000 metric tons in 1919 to 107,000 tons in 1920, but in 1921 it experienced a remarkable recovery, attaining in that year a total of 157,437 tons, which was more than 50 per cent. above the 1913 level of about 103,000 tons.

Both the importation and the exportation of the various oil seeds have been subject to wide variations. As a result, the quantity of seeds available for oil production has shown heavy fluctuations. This was, however, more pronounced before the war than it has been since.

The following table summarises the production of vegetable oil in the Netherlands during recent years:

Oils.	1913	1919	1920	1921
	Metric Tons	*Metric Tons*	*Metric Tons*	*Metric Tons*
Linseed ...	55,107	27,343	29,086	73,017
Coconut ..	10,602	43,823	45,672	64,942
Peanut ...	22,202	10,155	10,804	12,633
Rapeseed ..	10,784	7,374	11,308	5,238
Sesame ..	......	10,884	8,786	1,337
Soya bean..	1,313	3,273	364	177
Palm kernel	2,644	10,352	713	93
Total	102,652	113,204	106,733	157,437

The Dutch oil manufacturers are organised into an association known as the Vereeniging van Nederlandsche Oliefabrikanten (Association of Netherlands Oil Manufacturers). This association, which has 77 members, was established at Amsterdam in March 1912, and has for its purpose the advancing of the interests of the Dutch oil mills.

GREEK VALONIA PRODUCTION.

Valonia is the cap or beard of the acorn of the Greek oak and produces one of the strongest tannins known to the leather-making trade. It is used exclusively in Italy, Germany, the United States, and England. Two-thirds of the Greek output is exported through Patras. The 1922 crop was

generally inferior, owing to lack of humidity in April and May. This is a mid-summer crop, and dry weather increases the tannin content of the beard. The September top crop is very poor, and is used for mixing with July-picked valonia.

From a report by the United States Consul at Patras it appears that there are two distinct crops of this product: (1) Valonia collected in the southern Provinces of Laconia and Messenia (Peloponnesus); (2) Valonia collected in the northern Provinces of Aetolia, Acarnania, and Preveza (western mainland). The Laconia valonia is inferior to both the Messenia and the mainland product. In 1922 the southern production was 5,500 tons and the northern 3,500 tons, or a total of 9,000 tons.

Messenia valonia produces the highest per cent. of tannin and is always preferred by Greek tanners, while Italy takes most of that raised in Laconia. On account of the Smyrna disaster and the absence of Turkish valonia, British and American tanners were in the market for the Greek product, the latter buying 3,164,170 pounds in 1922, as compared to none in 1921. The best northern valonia comes from the mountain section east of the River Aspropotamo in Aetolia. British tanners took most of this product in 1922, while lesser amounts went to Italy, the United States, and Austria.

The quantity of valonia taken by the principal countries participating in this trade during 1919, 1920, and 1921, is estimated as follows:

Exported from Greece to—	1919	1920	1921
	Pounds.	*Pounds.*	*Pounds.*
Italy	1,710,527	4,179,247	2,441,208
Germany		1,209,271	2,535,556
France	306,760	83,490	76,606
Great Britain	3,084,281	1,651,629	320,181
Albania		112,870	227,203
Other countries	301,042	10,386	1,915,969
Total	5,402,610	7,246,893	7,516,723

GENERAL NOTES.

KAOLIN DEPOSITS IN EASTERN FINLAND.—Through investigations which a timber company has been carrying on for two years in eastern Finland, writes the United States Consul at Helsingfors, a large deposit of kaolin has been discovered, said to contain at least 200,000 tons, and extending deep into the earth. The deposits are situated in Wartsila, in the Prolanvaara Parish, about 20 kilometres from the Wartsila station, and are covered by a layer of moraine 4 to 6½ metres in depth. One of the engineers investigating the deposit states that the fireproof qualities of this kaolin are much higher than those of imported kaolin. It is of a pure quality, either white or brownish in colour, and especially well suited to the manufacture of porcelain. The discovery is important not only for the porcelain and allied industries but also for the paper industry, which has imported annually several thousand tons of kaolin. Two other kaolin deposits are known to exist in Finland, of which those at Puolanka are the richest, but they have not been used to any great extent on account of their distance from the railway and the consequent difficulties of transportation. The deposits at Wartsila, on the contrary, are easily accessible.

THE SEALING AND WHALING INDUSTRIES OF URUGUAY.—In his annual report on the economic and financial conditions in Uruguay, H.M. Vice-Consul at Montevideo states that the 1922 yield of by-products of the sealing industry of Maldonado was expected to surpass that of the preceding year, and to be greater than any yield for many years past. The sealing industry of Uruguay has become a valuable source of revenue to the country, so much so that in October last the Government appointed a commission to study the present mode of working and to suggest improvements for increasing the yield with a view to the nationalisation of the industry. This Commission received an offer from an American company to take over the entire output of skins and oil, but it was decided to offer these in public sale, although it is quite possible that in the future the Government will rent the working. The tugs arrived in December with the season's catch, bringing 2,600 fine sealskins, 4,000 ordinary skins and over 20 tons of seal oil. As regards whaling, Montevideo is made the anchorage during the winter months of the various flotillas owned by British and Scandinavian firms operating in the South Atlantic. The results of the last season were very successful, viz., 76,900 barrels of oil.

HAND-MADE LACE INDUSTRY OF GALICIA.—The production of hand-made lace is one of the most important industries of Galicia, writes the United States Vice-Consul for that Province. About 20,000 women are employed, and the total value of the product varies between 2,000,000 and 3,000,000 pesetas annually. All of this lace is produced in and around the small towns of Camarinas, Mugia, Vimianzo, Corcubion, Finisterre, and Muros, situated along the extreme north-west coast of Spain. In each of these places there are established small schools where lace making is taught to the peasant girls by an expert.

RAW COTTON SUPPLIES.—A statement made in Parliament by the Secretary of the Overseas Trade Department shows that during last year our imports of raw cotton from British possessions was in centals of 100lbs. as follows:—British India and Ceylon, 441,737; Anglo-Egyptian Sudan, 80,525; Nigeria, 62,067; Kenya and Uganda, 93,587; Nyasaland, 11,901; British West Indies, 16,509; South Africa, 14,903; Australia, 12,309; Other British Countries, 9,144.

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PROCEEDINGS OF THE SOCIETY.

HOWARD LECTURES.

DEVELOPMENT OF THE STEAM TURBINE.

By Stanley S. Cook, B.A., M.I.N.A., M.I.M. (Parsons Marine Turbine Co.)

Lecture II.—*Delivered May 7th*, 1923.

Synopsis.

The introduction of mechanical gearing.
Application to large powers in Naval vessels.
Lubrication of thrust blocks and bearings.
The Mercantile Marine turbine.
Comparison of modern and early efficiencies.
Methods of attaching blades.
Reaction and impulse types.
Progress in economy and output of land turbines.
The problem of the exhaust area.

Reference was made in the first lecture to the use of a combination of reciprocating engines and turbines in vessels where the speed was so low as to render a complete drive of direct coupled turbine unsuitable. The combination, however, was recognised to be but a temporary expedient. It was realised that the barriers to the use of turbines in low speed vessels would only be finally swept away by the introduction of some form of gearing, whereby a high speed turbine could be made to drive a low speed propeller, and both turbine and propeller left free to be designed, each to give its best efficiency.

Mechanical gearing for marine propulsion had actually been employed, as far back as 1897, with the turbine of a small launch of 10 H.P., built to the order of Mr. F. B. Atkinson, for his yacht "Charmian." This was, in reality, the second marine turbine to be built by the Parsons Company. It is, therefore, an interesting fact, and almost prophetic, that whilst the first turbine propelled vessel, the "Turbinia," was the pioneer of direct turbine propulsion, the second one to be built was the first to have a mechanically-geared turbine. This gear was single helical, one pinion driving two wheels, each coupled to one of the twin propellers.

Helical gearing had also been adopted in a few turbo-dynamos, one of them of 300 H.P., in which the turbine revolutions were 9,600, and those of the dynamo 4,800.

In 1909, when the turbine itself had been well established as an ideal instrument for ship propulsion, it was decided to explore this means of adapting it to the driving of low speed vessels. An old steamer, the "Vespasian," was purchased by the Parsons Company. The triple expansion reciprocating engines already in the ship were submitted to exhaustive consumption trials, and then replaced by geared turbines. A fresh series of trials were run with the latter. The results of these comparative trials with the two systems of machinery were given in a paper read by Sir Charles Parsons before the Institution of Naval Architects in 1910. An improvement in coal consumption of over 15 per cent. was obtained by the substitution of geared turbines for the original machinery.

The gearing was of the double helical type, two 5in. diameter pinions gearing, with a wheel of 8ft. 3½ins. diameter on the propeller shaft. These pinions were coupled, one to a high pressure turbine, and the other to a low pressure turbine, a disposition which has since become almost universal. Of greater importance than the gain in economy, was the demonstration that this experiment afforded of the practicability of such a system. The "Vespasian" was run between the Tyne and Rotterdam, carrying coals and general cargo for four years, and from first to last, the gearing gave no trouble. The hull, which was worn out, was then broken up. The turbines and gearing, however, were transferred to a new steamer, the "Lord Byron," which is still in service.

As is frequently the case, the problem which so long occupied the minds of

engineers met with more than one solution at about the same period. In 1910, by his experiments with the steamer "Vespasian," Sir Charles Parsons demonstrated the practicability of employing double-helical gearing to transmit the power from turbine to propeller. By 1912, two other forms of gearing had been successfully put to experiment, the hydraulic transformer by Fottinger, and the electric drive by Mavor in this country, and by the General Electric Company in America. Of these three systems of gearing, mechanical gearing, on account both of its greater simplicity and of its superior efficiency, has been the most widely adopted in the years that have followed. (A paper on the subject of electric propulsion was read by Mr. W.L.R. Emmett before the Institute of Naval Architects in March of this year.)

The success of the new system in the "Vespasian," led to its being tried shortly afterwards, with very satisfactory results, in the Channel steamers "Hantonia" and "Normannia," on the Southampton to Havre service of the London and South Western Railway, built by the Fairfield Shipbuilding and Engineering Company, and in the steamer "Paris," built by Messrs. Denny Bros., of Dumbarton, for the London, Brighton and South Coast Railway Co. After these vessels had been successfully put on service, the lead was quickly followed by other shipowners.

Whilst mechanical gearing was introduced primarily for the purpose of extending the field of utility of the turbine to the propulsion of low speed vessels, for which the revolutions of the propeller were too low to make direct coupled turbines an economical proposition, the advantage of freeing the turbine from the limitations to its revolutions imposed by the propeller was soon recognised to be of value, even in those fields of work which were then open to the direct-coupled turbine, and the latter has, consequently, now been completely displaced even in naval and high speed mercantile work by the geared turbine. The total output of geared marine turbines has now equalled that of direct turbines.

In the application of mechanical gearing to naval vessels, the increase to larger powers was at first made with caution. In the first destroyers to have this system of propulsion, H.M. Destroyers "Badger" and "Beaver," only the high pressure and the cruising turbines were geared, the low pressure turbine being coupled directly to the shaft. In 1912, however, the Admiralty adopted gearing for the whole of the machinery of two destroyers H.M.S. "Leonidas" and "Lucifer," each of 22,500 S.H.P. on two shafts. Exhaustive trials of these vessels shewed a considerable gain in efficiency, both at full speed and at cruising speeds.

The reduced propeller revolutions brought an improvement of propeller efficiency of about 12 per cent., and on account of increased K value, the steam consumption of the turbines per S.H.P. was reduced about ten per cent. at full power, and about 30 per cent. at one-tenth of full power. The new system greatly facilitated the provision of efficient cruising stages. There was also a slight saving in the total weight of the machinery.

During the war, gearing became universal for warships of the highest powers, and, as has been seen, finally supplanted altogether the direct driving turbines. More than 20,000 H.P. has been transmitted through a single pinion. The fitting of independent units, one on each propeller shaft, no longer presented any difficulty, and with the high revolutions of the turbine, the maximum efficiency could be provided. With the reduced propeller revolutions, the phenomenon of cavitation, and of propeller erosion which sometimes accompanied it, receded into the background. Turbines, both of the reaction type and of the impulse type, shared in this emancipation from the conditions which had previously hampered their design and limited their efficiency.

A full account of the adoption of geared turbines in vessels of the British Navy was given by Engineer Commander Tostevin, in a paper before the Institution of Naval Architects in March, 1920.

The gearing is of the double helical type, as in the "Vespasian," with flexible couplings between the turbine rotor and its pinion, to allow the pinion freedom of axial movement. Each half of the pinion thus takes an equal share of the load. The couplings also allow a small amount of lateral flexibility between the rotor and pinion. Single helical gearing has, however, been successfully adopted in some American destroyers. Helical gearing gives continuity of engagement, and smoother and quieter running than ordinary spur gearing. The helical angle in the "Vespasian"

was 23°, but in the immediately subsequent gears, it was made 45°. More recently, an angle of 30° has been generally employed. The teeth are of the involute type, the principal property of which is that the tooth surfaces can be generated automatically by the process known as "hobbing," the same tool sufficing for all wheels which have to gear together, irrespective of diameter.

The accuracy of the pitching of the teeth is dependent upon the accuracy of the master wheels of the gear-cutting machine. Most of the hobbing machines have, however, been fitted with a "creep" mechanism, by means of which the work is slightly accelerated with respect to these master wheels, so that the incidence of any errors is different in successive revolutions. An analogy to this is found in the principle of the hunting tooth, it being common practice in gear wheels which are to gear together to give the larger one a number of teeth, say, one more than an exact multiple of the smaller, so that every tooth of one wheel in the course of time comes into contact with every tooth of the other. The proper place, however, to apply the hunting tooth principle, is in the gear cutting machine rather than in the finished wheels, and this is virtually what is done when the "creep" mechanism is used.

To lubricate the gear teeth, oil is sprayed on to them near the line of engagement. The oil must be allowed to drain freely away from the teeth, and if there is any accumulation of oil in the bottom of the gear case, it must be kept well below the lowest point of the wheel.

The change from the old system, with its low turbine speeds, to the new, with speeds of rotation far in advance of any previously adopted in ship propulsion, as may be readily imagined, at once confronted the designer and builder with many new problems.

The first of these was the problem of the thrust block. With direct turbines, the thrust block was a simple matter. The thrust of the propeller was counter-balanced by the thrust of the steam on the rotor blades, and on a small shoulder provided on the end of the rotor. The ship was, therefore, really propelled by the pressure of the steam on the forward end of the turbine casing; and it is curious to reflect that, action and reaction being equal and opposite, all the complication of a propeller, a propeller shaft, and a rotor carrying blading arranged with close attention to hydro-dynamic principles, was only necessary in order (with the minimum loss of steam) to provide something for the steam to push against in the opposite direction without retarding the ship.

With gearing, however, it became necessary to reinstate the thrust block in its place of honour on the propeller shaft. In the "Vespasian," the original thrust block which had served with the reciprocating engines was retained for the geared turbines. With the higher shaft revolutions, however, of the first geared channel steamers and destroyers, we entered a new region of thrust block practice, and special means of cooling had to be considered.

Fortunately, the solution of this difficulty was then at hand in the Michell thrust block. Following up the researches of Osborne Reynolds, Michell in Australia, and, almost at the same time, Kingsbury in America, had developed means of establishing and conserving a film of oil between the fixed and moving surfaces of the thrust block, by fitting the fixed collars with rocking pads pivoted each on a radial line slightly in advance of its centre of figure. In action these pads tilted back (see Figure 7), to

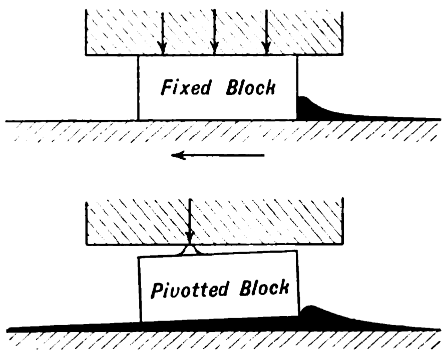


Fig. 7

form a wedge-shaped space, into which the oil was entrained by the rotating collar by viscous friction. The surfaces no longer rubbed metal to metal, but were separated by a continuous thin film of oil. The friction was enormously reduced, and very high pressures could be carried with safety.

It is found in practice that such blocks function perfectly well if the pivot is immediately in line with the centre of figure, and many have been made that way.

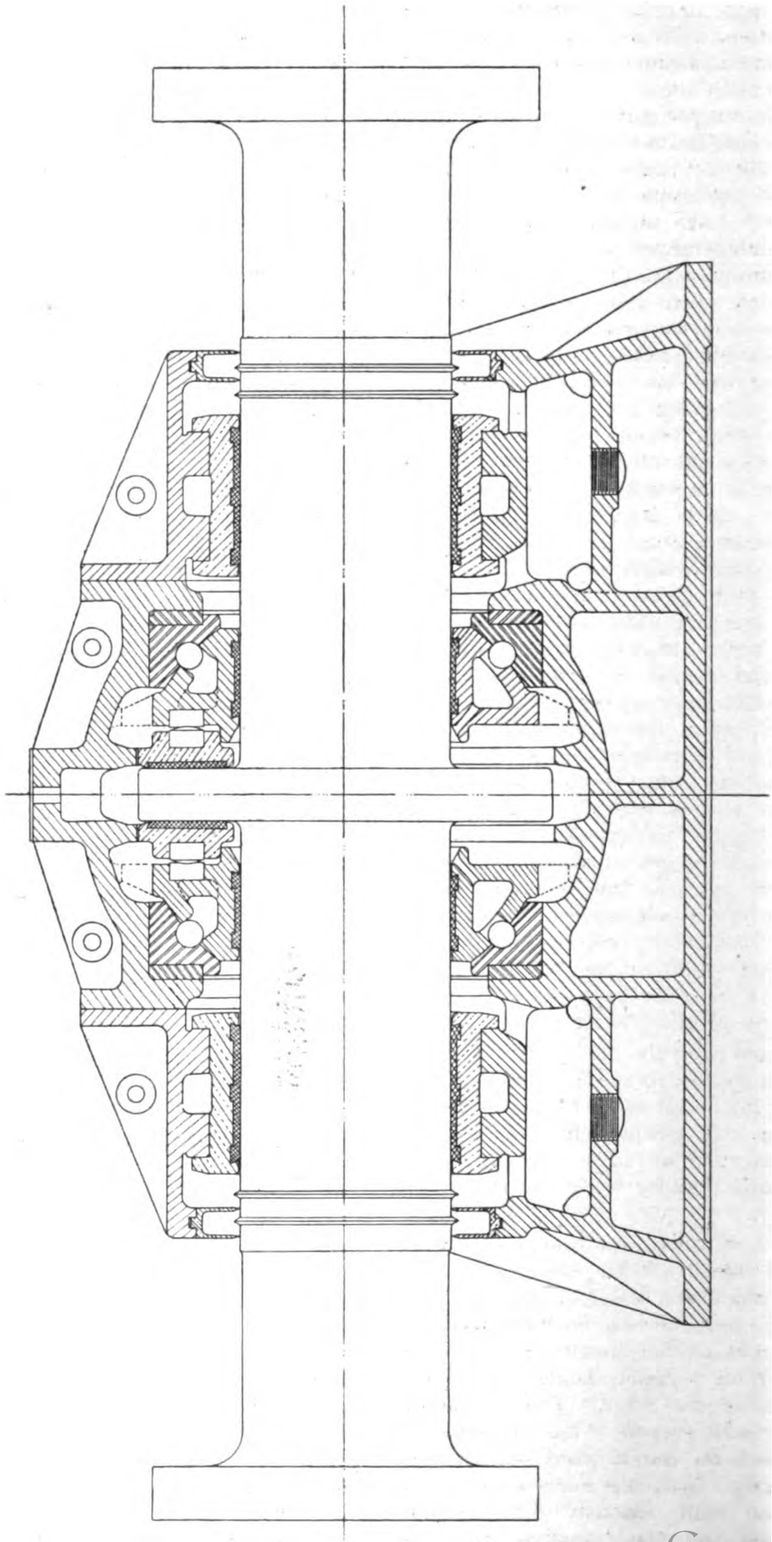


FIG. 8.—Main Thrust Block.

At the time, only small blocks had been tested with pads about two square inches in area, but realising its potential value, the Parsons Company immediately put in hand an experiment on a large scale block, representative of the thrust block required for a geared destroyer, with a total thrust of about 40,000 lbs., and four pads each of 33 square inches surface. The thrust was safely carried at a pressure of 300 lbs. per square inch. In further experiments, it was found possible to carry thrusts as high as 3,000 lbs. per square inch. In fact, the limit to the pressure that could be safely supported in this way was found to be the pressure at which the white metal itself, with which the blocks were faced, began to flow.

After this demonstration, the pivoted thrust block was adopted with confidence for propeller shafts of geared turbine vessels, and is now a standard accompaniment of the geared turbine. The whole of the thrust is carried on a single collar. The first vessel to have it fitted was the S.S. "Paris," built by Messrs. Denny Bros., of Dumbarton. Figure 8 shews a main thrust block of this type.

The introduction of the new principle for thrust blocks led to a more thorough realisation of the true principles of lubrication of journal bearings, which, although demonstrated by the experiments of Beauchamp Towers in 1883, had not hitherto been properly recognised in engineering practice. In the wedge-shaped space near the lines of contact of the cylindrical journal and its bearing, which is, or should be, a slightly larger cylinder by the amount of the clearance allowed, we have ideal conditions for the establishment of a film of oil by viscous friction, provided the oil is properly led in. It was customary to provide grooves in such bearings to lead the oil to the point where it was supposed to be required, the "crown" of the bearing, in other words, the point or line of greatest pressure. With the then customary load of 80 to 100 lbs. per square inch, and a pressure of supply of only 10 lbs. per square inch, it was clearly impossible by this means to make the oil support the journal. The oil is now led to the bearing at a point as far removed as possible from the point of greatest pressure, and is entrained into the wedge shaped space at the "crown," by the motion of the surface of the journal. Under these conditions, pressures are produced in a thin film analogous to those we have mentioned for the pivoted thrust block. This pressure varies with the thickness of the film, which is, therefore, determined at a certain surface speed by the load upon the journal. The journal, in fact, rises on the film, the friction is merely the viscous friction of the film of oil, and there is no appreciable wear of the metal surfaces, which only come into contact when the spindle is stopped.

This reform was immediately put into practice, and a hot bearing, until then not an uncommon thing, has since become, except through failure of the supply of lubricant, an unknown occurrence. In view of the increased surface speeds, and the increased number of bearings when gearing is adopted, this reform in bearing practice was of great value to the new system. It is now not at all unusual to have bearing loads as high as 200 lbs. per square inch, and even this is recognised to be a conservative figure.

Attempts have been made in theory to apply this same principle to the lubrication of gear wheel teeth. But it is fairly certain that the action there is of a different kind. The space between the convex surfaces of two gear teeth in contact is of very different proportions from that under the pad of a pivoted thrust block, or between the two cylindrical surfaces of nearly equal diameter of a journal and its bearings. The relative curvature is usually more than a thousand times greater in the case of the two surfaces of the gear wheel teeth. Moreover, there is no need to seek to apply the same principle, for the contact between these surfaces lasts only for a small fraction of a second, and the lubrication of the surfaces is continually renewed between the intervals of contact.

In by far the majority of geared turbine installations in marine work, the condenser is underslung beneath the low pressure turbine casing, an arrangement which was hardly possible when the turbine was direct-coupled to the propeller shaft. The underslung condenser eliminates strains arising from difference of expansion between turbine and condenser, improves the vacuum in the turbine exhaust, because there is now no exhaust bend with its inevitable resistance, and at the same time permits free drainage of the water of condensation from the turbine.

The largest ratio of reduction adopted

with a single step from turbine to propeller shaft was 26 to 1, in the case of the "Cairnross," a mercantile vessel built in 1912, which was sunk during the war. It was soon recognised that in mercantile work, to obtain full advantage of the economy of high speed turbines, a still larger ratio of reduction was required, and this led to the adoption of a double reduction. The development of mercantile work was, however, interrupted by the war, and it was not until 1918 that the first marine double reduction gear was fitted in the S.S. "Somerset," a steamer of 4,500 S.H.P. at 13 knots, built by Messrs. Earles Shipbuilding Co., Hull, to the order of the Federal Steam Navigation Co.

An interesting feature of this installation is that it comprises three turbines, a high pressure and an intermediate pressure turbine on one side of the main gear, and a low pressure turbine on the other. Figure 9 is an illustration of an installation of this type. The sub-division of the high pressure unit into high and intermediate brought several advantages. It enabled them to be given higher revolutions and smaller diameter with considerable gain of efficiency, a more rigid construction and increased reliability. The "Somerset"

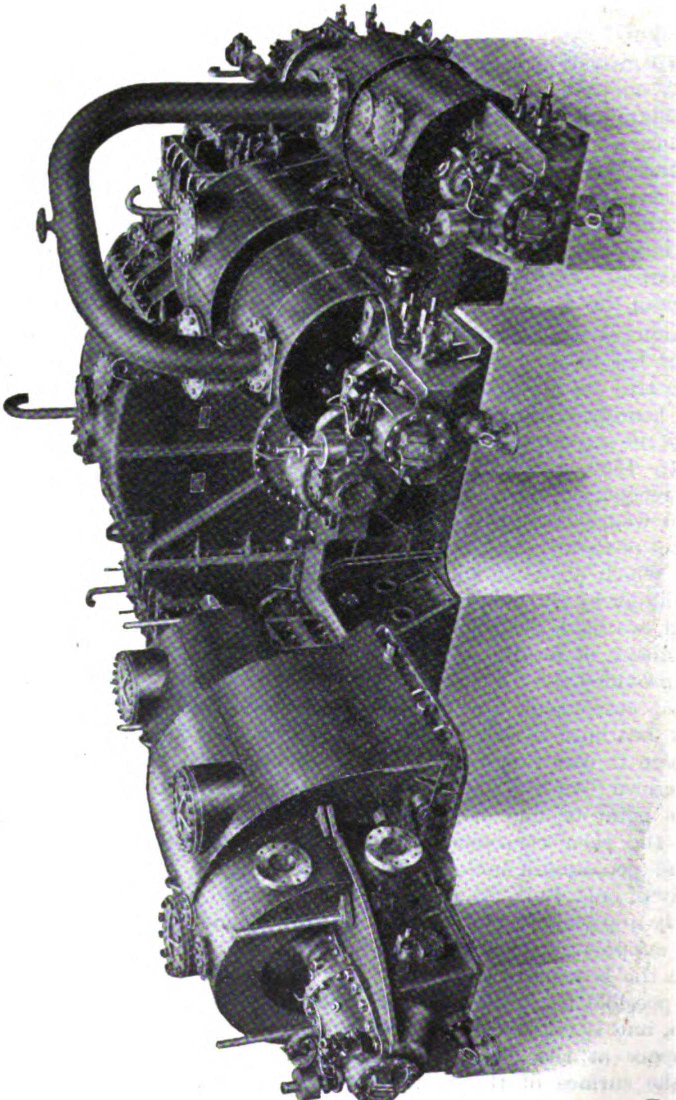


Fig. 9.

has steamed, up to the present time, a distance of over 200,000 miles, or about eight times round the globe. Since she was placed on service, there have been over 200 British built mercantile vessels fitted with double reduction geared turbines. In some installations with three turbines, for the sake of simplicity in the construction of the gearing, the H.P. and I.P. turbines have been arranged in tandem driving one primary pinion, while the L.P. turbine drove the other. Figures 10 and 11 are illustrations of turbines of this type in the S.S. "Cairnross," a single screw steamer of 3,150 S.H.P., built in 1920 by Messrs. Short Bros., of Sunderland, and engined by the Parsons Marine Steam Turbine Co., for Messrs. Cairns Noble & Co. The propeller revolutions are 80 per minute, the H.P. and I.P. turbines run at 3,200 revolutions, and the L.P. turbine at 2,350 revolutions per minute. The H.P. turbines are fitted with the end-tightened blading, which is so widely adopted for land turbines, and which will be described later.

It is interesting to make a comparison of the efficiencies of the present day with those of the earlier marine turbines. In the early direct turbines, the steam consumption was from 15 to 16 lbs. per horse power hour. With a three-turbine geared installation, the consumption is under 10 lbs. per S.H.P. hour for saturated steam, and under 8 lbs. with superheat of 200°F. If we take into account the improvement in propeller efficiency, it will be seen that the overall efficiency has been more than doubled, a remarkable progress to record during a period of 20 years.

And this improvement has been effected by following out the principles enunciated in the previous lecture. The use of gearing has allowed compounding to be carried nearly to its maximum point. The total value of the co-efficient K in the "Cairnross'" ahead turbines, is 356, or more than three times that of the early turbines. Leakage losses have been reduced in virtue of the small dimensions of the turbines, and by the use of end-tightened blading. Frictional losses have been reduced by a correct application of the principles of viscous friction. The blade profiles are of practically the same shape as in the early turbines, careful experiments of recent years having failed to evolve any improvement upon them; and the turbine is still the same simple mechanism. It consists of blades fixed and moving, and the structure to carry them; the rest of the turbine, in fact, exists for the sake of the blades, to maintain them stiffly in their relative positions, to conduct the steam suitably to them, and to transmit their turning effort to the propeller shaft with the minimum of friction. Thus we have a rigidly constructed rotor to which the moving blades are attached. Alternating with the rings of moving blades on the rotor are rings of blades fixed in a rigid casing. The steam, admitted to the turbine at a pressure of say, 200 lbs. per square inch, forces its way through the successive rows of fixed and moving blades, and passes on from turbine to turbine, and finally to the condenser.

To retain the rotor in its longitudinal position, there is a small thrust block, called the adjusting block, which is now always of the pivoted type. In the turbines illustrated in Figures 10 and 11, this block is allowed to carry the whole of the end thrust of the steam.

The glands where the rotor shaft passes out of the ends of the turbine, and the bearings, the lubrication of which has already been mentioned, complete the list of the essential parts of a turbine.

The method of attaching blades most commonly adopted for the reaction type, is by caulking suitably shaped distance pieces between the blades in grooves in the rotor or casing. The roots of the blades and the sides of the grooves are serrated, and the distance pieces which are annealed soft, when caulked, fill out into the serrations and make a compact attachment, the blades being held by the distance pieces, and the distance pieces by the grooves. The end of the caulking tool is provided with a small recess which leaves a witness mark in relief on the distance piece; this avoids the danger of any one piece being accidentally passed over without caulking, and enables an inspector to see at a glance that caulking has been properly carried out. With this method the strength of attachment of brass blades is found to be practically equal to the breaking strength of the blades themselves.

For modern land turbine blades, however, brass and copper alloys have been gradually superseded by steel. The use of steam with a high degree of superheat requires for the blading at the high pressure end a material which retains a good tensile strength at the full temperature of the

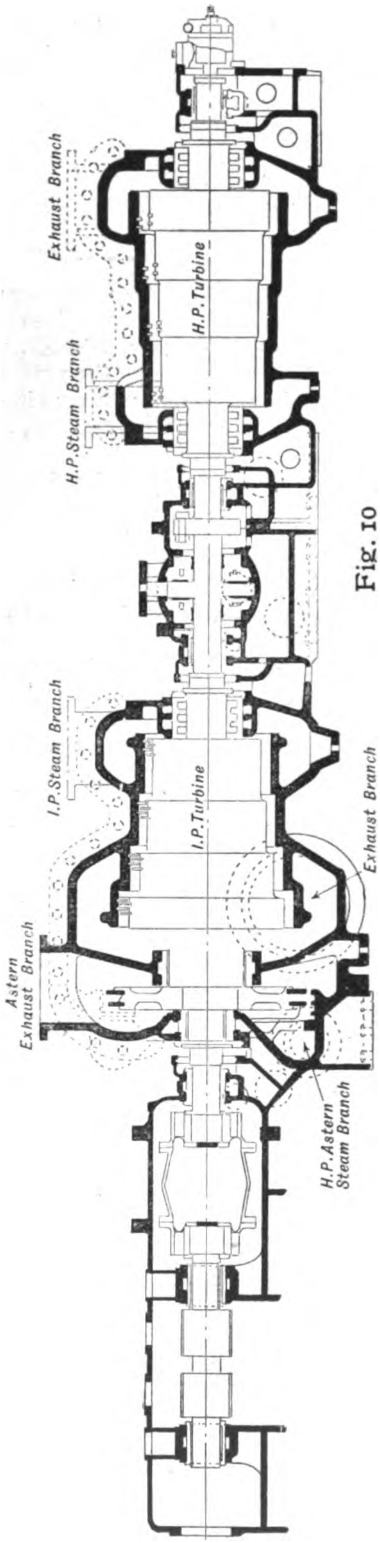


Fig. 10

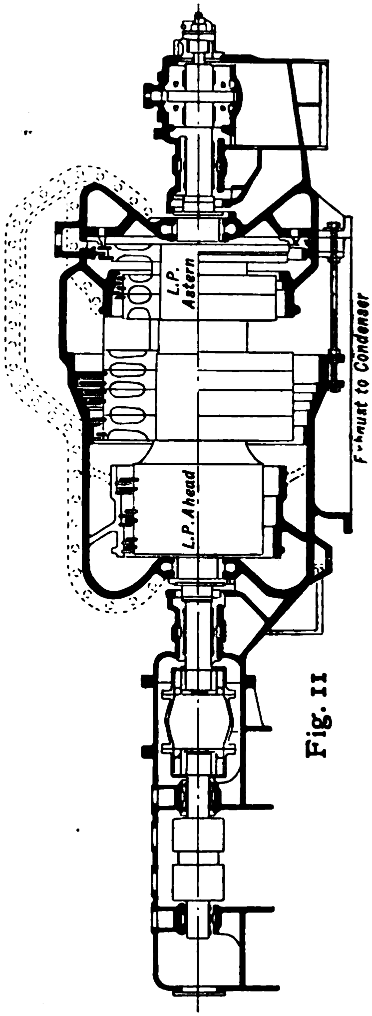


Fig. 11

steam, while at the exhaust end of the turbine high peripheral speeds and long blades demand high tensile strength. Concurrently with the introduction of new materials to meet the increased stresses in blades themselves, new methods of fixing the blades in the rotors have had to be devised to give a proportional increase in the strength of the attachments. For this reason the practice of swelling the spacing pieces into the serrations of the spindle grooves by caulking has been replaced by the use of blades with serrations milled on the roots, or having the roots dovetailed. This is known as integral blading and is sometimes adopted, even where stresses are not severe, in order to eliminate the risk of inefficient caulking. When the blades are placed in position these root serrations interlock with corresponding

serrations in the spindle grooves, and the depth of the grooves and the number of serrations can be so arranged as to give ample strength to meet any stress conditions.

The tips of the blades are sharpened to a thin edge. It is an important principle observed in the Parsons' turbine, that wherever two parts are moving in close proximity at high relative speed, one of them must be provided with fine edges. Contact should not be allowed to take place, but it is an assurance to know that in the event of accidental contact, the damage will be limited to a slight rubbing of the fine edge. With broad surfaces, in accidental contact, destructive heating effects might occur.

Figures 12 and 13 illustrate another blade formation, commonly known as the "rosary" system. The blades and distance pieces are drilled in suitable jigs and strung on a wire. They are driven well up together in temporary grooves, the ends of the group silver-soldered to the wire, and binding strip attached by silver solder. By this means they are made into a compact sector of blades, and are then transferred to the grooves of the rotor or casing, into which they are fixed by caulking as before. This method enables a good deal of the work of blading to be done before the rotor or casing is ready to have the blades fitted; it was found very advantageous for large direct driving turbines, but for geared turbines in which the quantity of blading is much smaller, because, with higher speeds, fewer rows are required, it is not often now adopted.

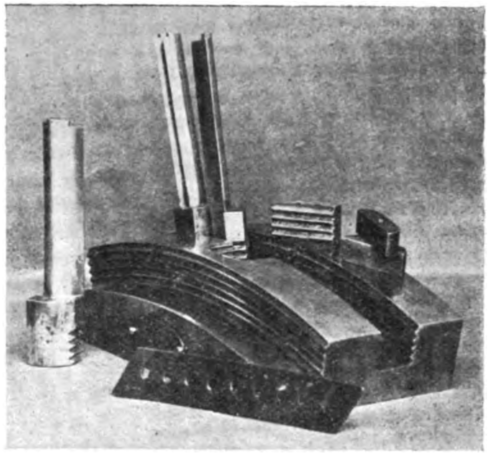


Figure 14 is an example of the "integral" blading just referred to. Impulse blades of

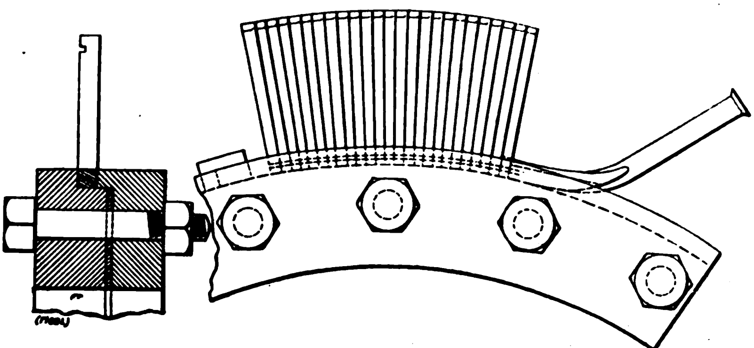


FIG. 12.

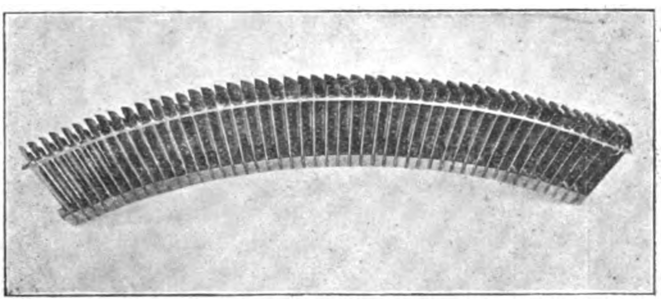


FIG. 13.

this type must be threaded along the groove from an enlarged space arranged at one part of the circumference. With reaction blades this is not necessary. They can be inserted at an angle and twisted into their position in the groove. For the fixing of the last blade, a suitable locking piece must be provided. The necessity for a locking piece is avoided, however, in the method illustrated in Figure 15, in which the groove is made wider, and side caulking strips filled in behind the blade root. This makes a very simple and satisfactory attachment. The combined blade and root may be machined out of the solid. A method was developed a few years ago for extruding blades with roots left on them which were afterwards machined to the required shape; blades formed in this manner were, however, found less reliable than rolled blades, due to the narrow limits of composition of the blade material suitable for the extrusion process. Messrs. C. A. Parsons & Co. have recently developed a process for rolling blades, integral with their root pieces, from "L" shaped billets.

Another method of attaching blades is adopted in the Rateau type of turbine, where each row is attached to a separate disc. The root of the blade is forked, fitted astride the rim of the wheel and fixed by rivets.

Figure 15 is an illustration of the end tightened blading, which was introduced in 1901, and has for the last 11 years been regularly adopted in land turbines of the reaction type. Some clearance must be provided between revolving blades and the fixed casing, and again between the fixed blades and the rotor. With this type of blading, such clearance is in the axial direction. Because of the positive nature of the control of the end position of the rotor by the thrust block, in view of the rigid construction of the rotor, clearance in this direction can be made small with greater safety and radial clearance over the tips of the blades may then be left large without prejudice to efficiency. It will be seen that the blades are fitted with complete shrouds having an overhanging sharp edge. This edge runs in close proximity to the roots of the blades of the adjacent row, and the clearances between the shrouds and the roots of the adjacent blades can be adjusted and regulated by end movement of the rotor.

Mention has already been made of the two different types of blading which characterize what are called reaction turbines and impulse turbines, and before passing on to a discussion of the development of land turbines, I propose briefly to refer to the fundamental features of reaction, impulse and compound impulse blades.

All turbines are really driven by "re-

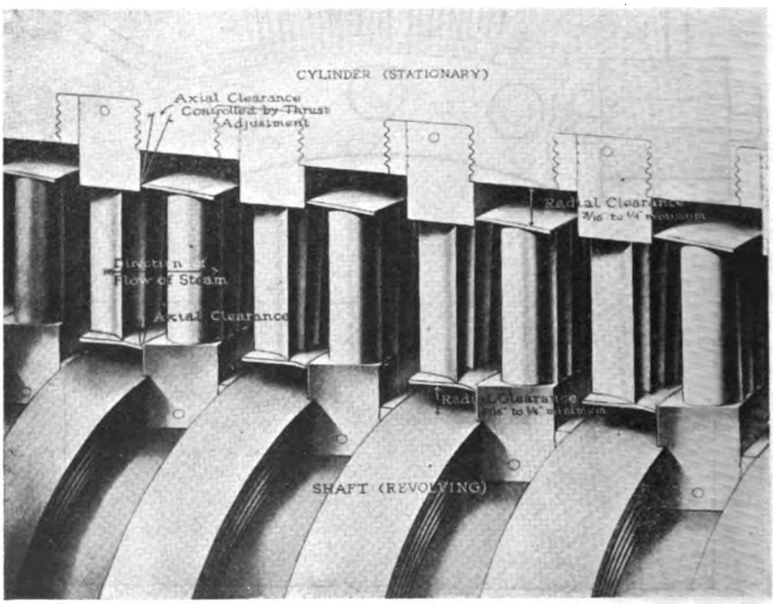


Fig. 15.

action," the force on the moving blades being entirely derived from the alteration of velocity of the working fluid in passing through the blade passage. But this may be done in different ways. Thus we may have a blade as in Figure 16, in which the

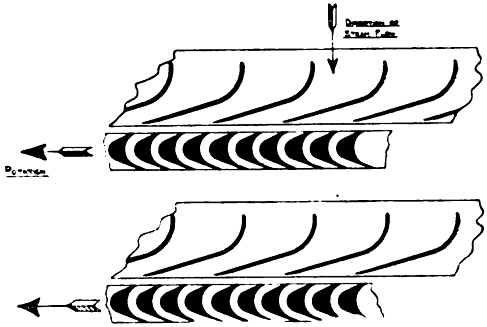


FIG. 16.

steam jet is merely diverted in direction without change of magnitude. Apart from loss by skin friction, this change of direction compounded impulse type, each wheel with its preceding nozzle working on a portion of the range of expansion of the steam.

On the other hand, we may have moving blades in which the passages are convergent, as in Figure 18. Such blades are really moving nozzles, the steam must increase in velocity as it traverses them, and this increase in velocity will be accompanied by a drop in pressure. These blades equally require a preceding jet, which must supply steam at such a velocity that, in spite of the relative motion, it may enter the moving blade with the small velocity appropriate to the enlarged area at entry. The jet in this case is a fixed blade of the same shape. The driving force on such a blade is derived almost entirely from the momentum of the discharge. A pair of such blades, one fixed and the other moving, constitutes the so-called reaction blading of the Parsons' turbine.

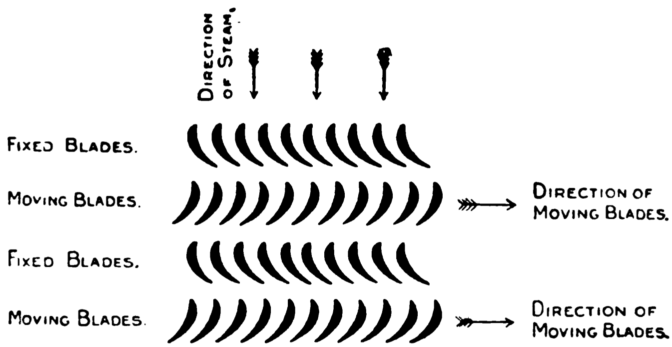


FIG. 18.

absorbs no energy, and the pressure will be the same at exit as at entry. Energy is absorbed, however, in supplying the jet at entry, for which a fixed nozzle is required, giving a steam jet of still higher velocity on account of the relative motion. Such a combination of fixed jet and moving blades constitutes the so-called impulse blading of the simple type, as developed by De Laval and Rateau.

The earlier De Laval turbine consisted of a single impulse wheel running at the enormous speed of 10,000 to 30,000 revolutions per minute, with nozzles of the diverging type giving jets of steam at speeds in the neighbourhood of 3,000 feet per second.

The Rateau turbine consists of a series of simple impulse wheels running at a more moderate speed and separated by diaphragms as shewn in the illustration Figure 17. This type of turbine is called the pressure-

Of this type of turbine there are, at the present time, two principal examples—the Parsons Turbine and the Ljungstrom Turbine. In the Ljungstrom Turbine, instead of one blade of a pair being fixed and the other moving, both blades are moving, but in opposite directions, so that it is the same in effect as if the casing of the Parsons turbine were allowed to revolve in a direction opposite to that of its rotor. This enables a high relative speed to be maintained, and, consequently, a higher K value on the same mean diameter. The blades in the Ljungstrom turbine are arranged so that the steam flows radially outwards, the blades being attached to two discs mounted with a common axis, and revolving in opposite directions. (See Figure 19.) This turbine embodies all the characteristics that I have previously referred to, as making for efficiency. First of all, it has blading of the

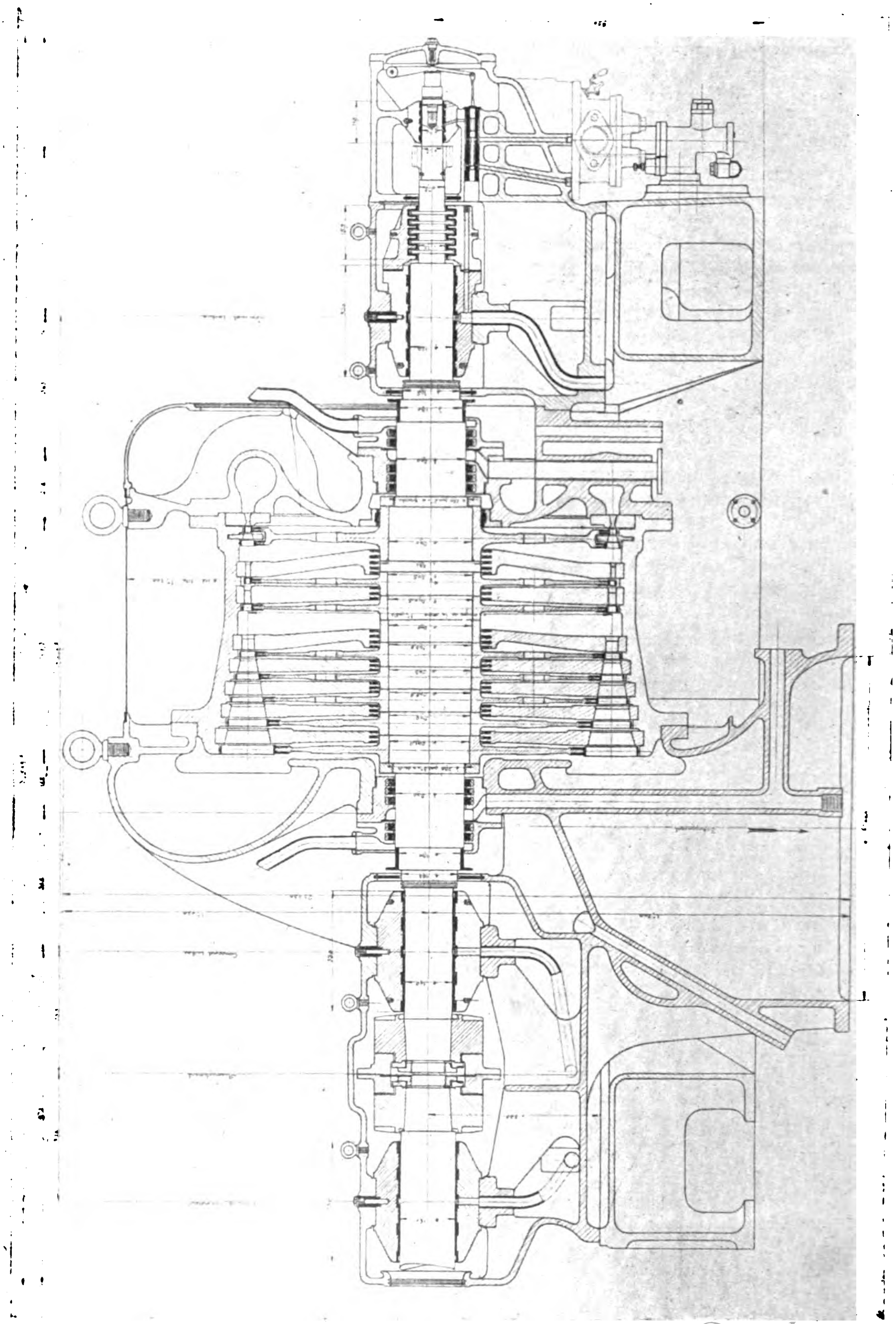


FIG. 17.

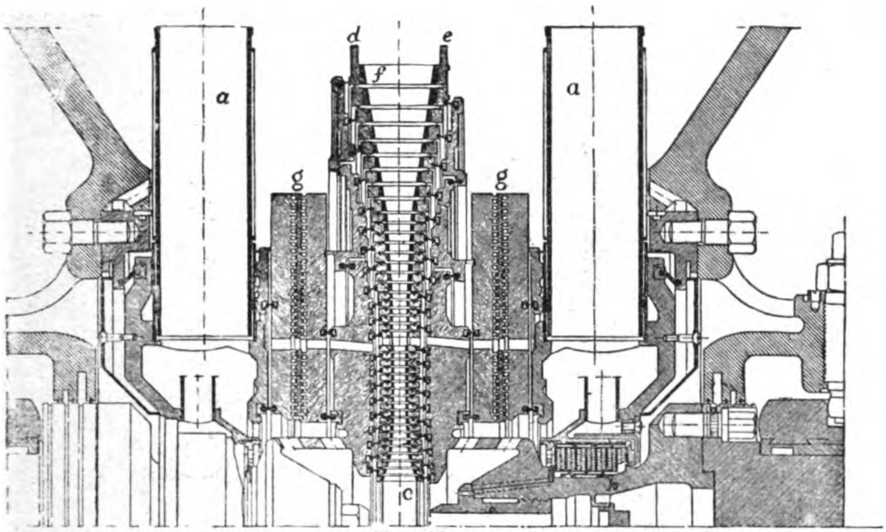


FIG. 19.

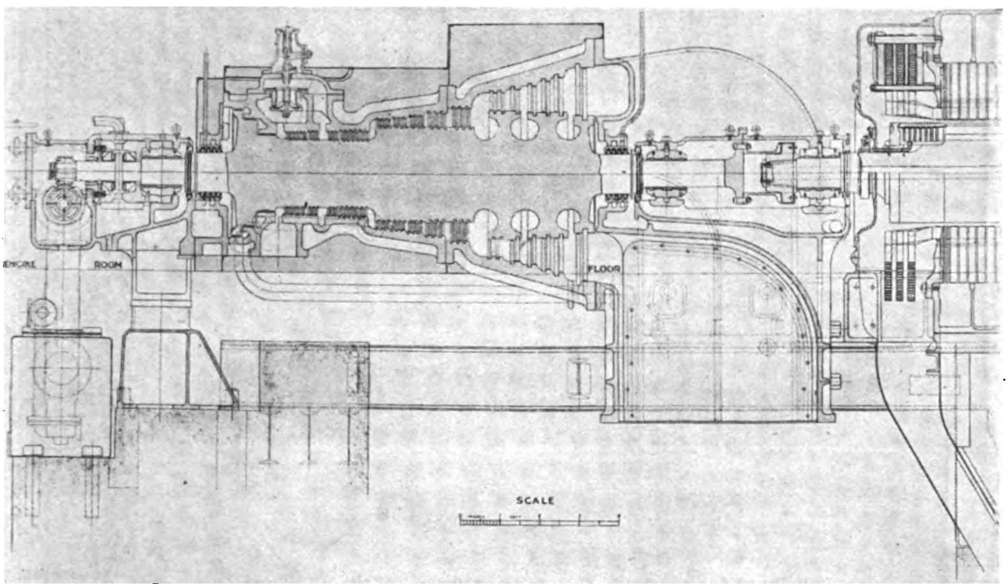
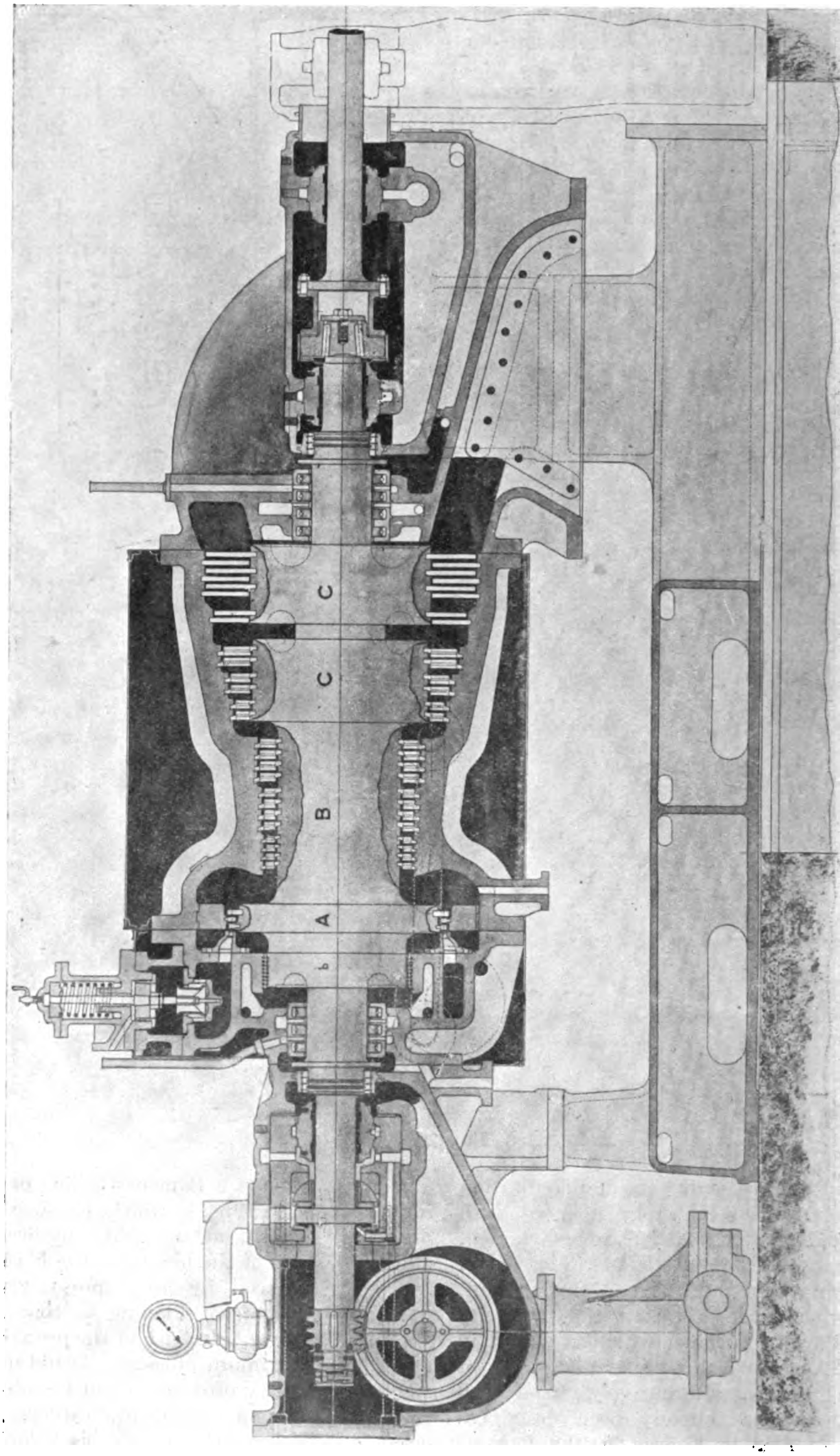


FIG. 20.

reaction type; secondly, the double rotation principle enables a high relative speed, and, therefore, high values of Σu^2, to be attained, and leakages are kept down, as will be seen in the drawing, by a multiplicity of fin packings. The only thing that it lacks is the simplicity of the Parsons turbine, which is shewn in Figure 20, and which consists of a series of reaction blades, alternatively fixed and moving, and has already been described. As will be seen in Figure 20, the Parsons turbine is characterised by the entire absence of diaphragms.

Figure 21 shews a Parsons turbine of the impulse reaction type, in which, for the sake of overall length, at a slight sacrifice of efficiency, some of the high-pressure blading has been replaced by an impulse wheel.

A third system of blading is that developed by Curtis. In both of the preceding types, the maximum efficiency is obtained when the velocity of discharge of the steam from the moving blade, or, rather, the circumferential component of this velocity, is equal to the velocity of the blade itself in the opposite direction. As far as circum-



LONGITUDINAL SECTION THROUGH TURBINE.

FIG. 21.

ferential motion is concerned, the steam has then been brought to rest. Its high velocity is only relative to the moving blades. If the speed of the blade is less, however, the steam will not be brought to rest in the space following the blade, and some of its energy will consequently be lost. The object of Curtis was to employ high steam velocities and low blade speeds, and still to provide means of recovering this residual energy. This was achieved by fitting additional guide blades to re-direct the steam on to further rows of

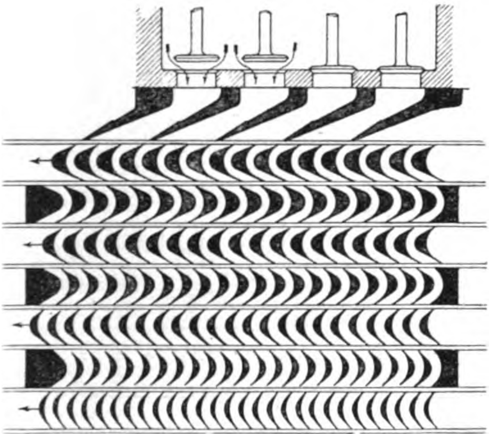


FIG. 22.

moving blades. Figure 22 shews a series of such blades. The characteristic feature is that pressure drop is confined to the nozzles, the steam flowing through the remaining blades at constant pressure, but with ever diminishing velocity, because of the relative motion of alternate rows of blades. This is known as velocity compounding. It might be supposed that these rows could be made sufficiently numerous to extract the whole energy economically in a single stage, but the friction of the high velocity steam soon imposes a limit. The relative efficiencies of these three types of blading are best seen from Figure 23, in which R is the curve of efficiency of reac.ion blading, A of single row, or "Rateau," impulse blading, B of "Curtis" blading with two moving rows, and C of "Curtis" blading with three moving rows. The maximum efficiency realisable diminishes as we increase the number of rows, although this maximum is obtained at a lower velocity ratio with the larger number.

The friction of the steam in the blades following the nozzles is the explanation

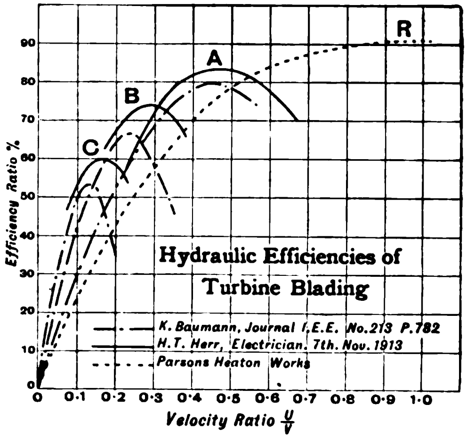


FIG. 23

of the inferior efficiency of impulse blading. The efficiency of reaction blades is equal to that of well formed nozzles. In recently published experiments on steam jets, by the Institute of Mechanical Engineers' Research Committee, Professor Stoney, giving their efficiencies at various speeds, shews a considerable falling off of efficiency as the speed of issue from the jet increases, from which it would appear that the efficiency of reaction blading with its lower steam speed will be somewhat higher than the nozzle efficiency of impulse blading.

In the first lecture, reference was made to the early promise of the turbine, and, in its application to marine work, its progress was traced in three directions: increase of capacity, increase of efficiency and extension of its field of application. In all three directions, its progress has been extraordinary. In land turbines similar progress is to be recorded, and has been attained along the same avenues.

In 1907, what was at that time a record in both output and steam consumption had been created by Parsons' steam turbine and alternator of 5,000 kilowatt capacity, installed at the Carville power station of the Newcastle-upon-Tyne Electric Supply Co. To this turbine, steam was supplied at a pressure of 200 lbs. per square inch, and superheated 120°F. With a condenser vacuum of 29ins., the steam consumption was 13·2 lbs. per kilowatt hour at full load, and the efficiency 63·6 per cent. of the maximum possible with a theoretically perfect engine working between these initial and final conditions.

In 1913 a new record in output and also in overall efficiency was created by a

Parsons' turbo-alternator installed at the Fisk Street Station of the Commonwealth Edison Co., of Chicago, U.S.A., capable of a continuous output of 25,000 kilowatts at 750 revolutions per minute. With an admission pressure of 200lbs. per square inch, 200°F. superheat, and a condenser vacuum of 29″, the steam consumption was 10.42lbs. per K.W. hour, representing an efficiency of 77%. A sectional view of this turbine is shewn in Figure 24.

Accordingly, we find that the temperature at which the steam can be condensed by the cooling water available determines our limit in this direction. The temperature of steam at 29in. vacuum is 79° F. A reduction of this temperature to 70° F. would increase the energy available for conversion by about three per cent. In turbines of large output, however, the utilisation of the lowest limits of temperature presents the designers with a serious

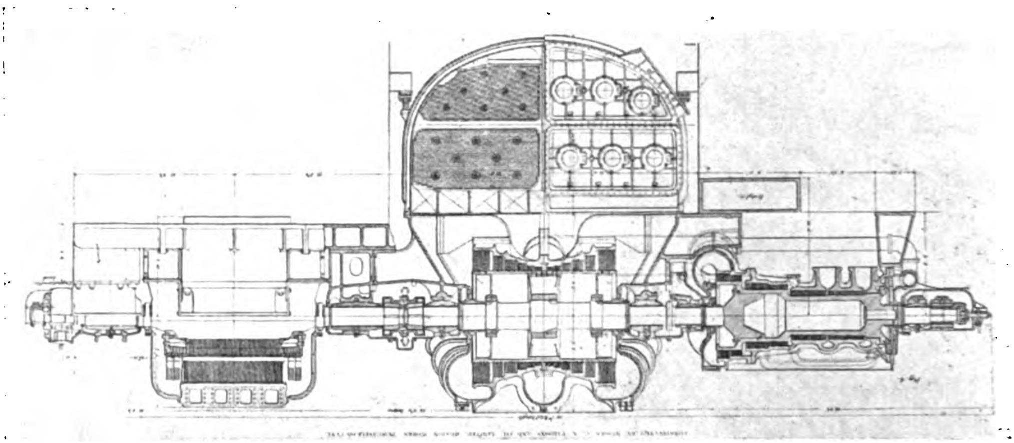


FIG. 24.

problem. If no increase in exhaust area is made, practically the whole of this three per cent. gain of available energy would be absorbed in the increased kinetic energy of the exhaust steam, which energy is lost to the system.

Another record was established in 1915 by the first of a series of five Parsons' turbo-alternators, of 10,000 K.W. capacity at 2,400 revolutions per minute installed in the Carville Power Station above mentioned. The admission pressure was 250lbs. per square inch, superheat 300° F., and condenser vacuum 29″. This was the largest alternator to run at that speed, and gave the lowest recorded steam consumption, viz., 10lbs. per K.W. hour. In this case, however, the improvement in consumption was due to higher steam pressure and temperature, the admission pressure being 250lbs. per square inch and the superheat 300° F. The overall efficiency was 72.85.

Still larger units are under construction at the present time, which will be referred to in my next lecture.

Reference has been made to the ability of the turbine to utilise large expansion ratios, and extract the energy from the steam down to the lowest limit of pressure. In a theoretically perfect engine, the proportion of the supplied heat that can be converted into work depends upon the ratio of the initial to the final temperature.

Attempts have been made to recover a part of this kinetic energy by means of a "diffuser," such as is commonly adopted in some water turbines, in which the velocity energy of the water at exit from the turbine is partially re-converted into pressure. The most that can be done in this direction, however, is to shape the exhaust passages so as to give an easy flow to the condenser, without further appreciable drop in pressure, the surface friction of these passages being overcome at the expense of the kinetic energy rather than of pressure drop. This necessitates a gradual increase in area from the end of the turbine to the condenser.

Figure 25 is an illustration of turbine exhausts shewing the evolution of the diffuser principle.

The problem of the loss of kinetic energy of the exhaust steam can be looked at from various sides. With given condenser

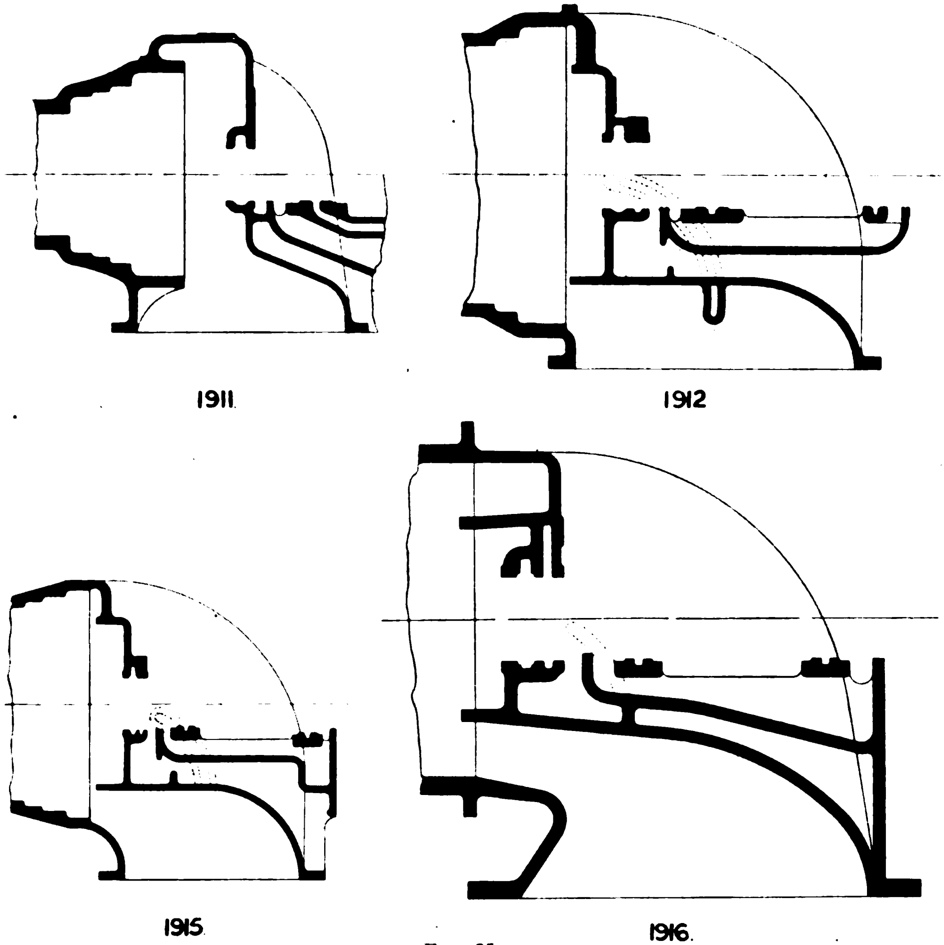


FIG. 25.

vacuum, we may consider means for increasing the exhaust area and so reducing this loss—or we may endeavour, again by increasing the exhaust area, to reduce the back pressure and make more energy available, without increasing the kinetic energy of the leaving steam. Or we may desire, without increase of leaving loss, to increase the output of a machine of given size. Whichever way the subject is approached, we are forced to the consideration of means of increasing the exhaust area.

The method commonly employed by the Parsons Company in large turbines is to divide the flow of the steam when it has been expanded to about atmospheric pressure, into two parts, each part flowing through one half of the low pressure turbine, which is double ended, and has two exhaust pipes. It will be clear that by this arrangement, for a given vacuum and quantity of steam, the leaving velocity is halved, and the leaving loss, therefore, reduced to one quarter, or conversely, with the same leaving velocity, double the output can be obtained, since twice the quantity of steam is dealt with; moreover, two exhaust pipes are provided, and generally two condensers.

This provision of additional area is, however, only necessary at the last two or three rows of blading, since in the preceding stages the volume of the steam is quite manageable; it is only at very low pressures that the volume becomes so enormous. Advantage is taken of this fact by some makers, who double only the last row or rows of blading, and so shape the passages that it can be accomplished in one cylinder, without using high and low pressure units.

Another way of achieving the same result, namely, the provision of additional

area in the last row, is advocated by the Metropolitan Vickers Company, of Manchester. Here, instead of conducting portions of the low pressure steam to the additional blade rings by means of ports or passages in the turbine casing, these portions of steam are passed through inner annuli in the preceding rotor blade rings. It is claimed that the gain by the increased area so provided is greater than the loss due to the obstruction by the vanes of the inner annuli. It is questionable whether better results on the same overall length cannot be obtained by duplicating the low pressure portion as previously described.

A simpler method which has been frequently employed for reaction blading, is to make the blades of the last stage of varying section and discharge angle. This permits a greater ratio of length of blade to mean diameter without increasing the stress in the supporting discs of the rotor. Similar methods have been employed with impulse blading.

Probably the best solution of the whole exhaust area problem in large machines is to reduce the revolutions of the last portion of the turbine, in a supplementary turbine arranged in the closest possible proximity to the condenser. This enables large areas to be provided without excessive stress in the blades or in the discs which carry them. Figure 26 shews an arrangement of this description.

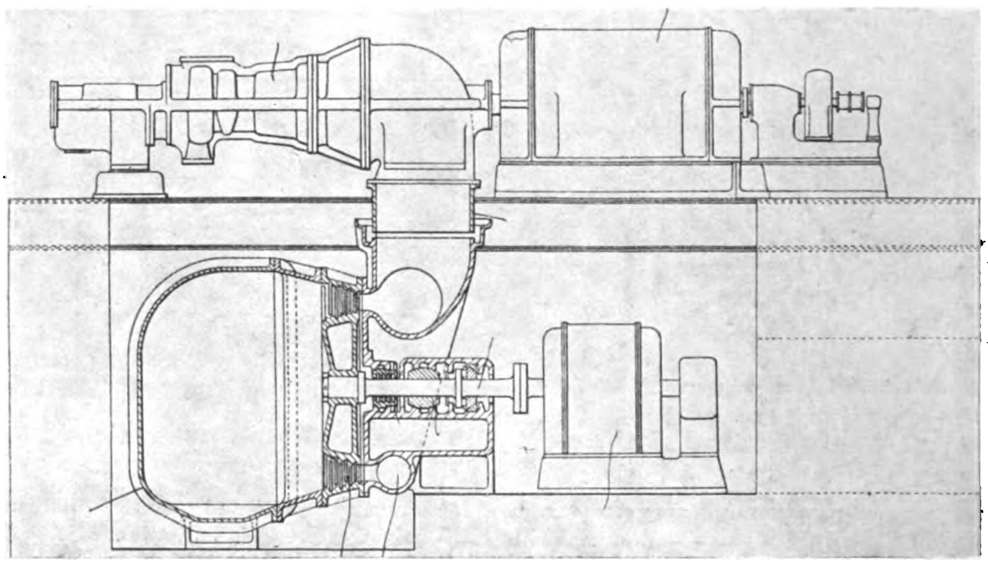


Fig. 26.

THE CHINESE TUSSOCK MOTH.

The eggs of the Chinese Tussock Moth (not tussur)—*Antheræa pernyi*—are reared in the following manner.

When the moth is about to lay eggs, a projection appears at the end of its abdomen. The sericulturist immediately places the moth in a small bamboo cage, where the eggs, 70 to 100 in number, will be laid. The colour of the eggs is at first between purple and black, but gradually turns green. Their shape is not exactly round, but flattened on two sides. They are covered with a thick fluid, which holds them to the cage.

To remove the eggs, they are washed off the cage with water, which also washes away the thick fluid. Fifteen to twenty eggs are placed on a slip of paper of about five inches long and 4/10th of an inch wide. When it is about time for the larvæ to come out, the eggs are placed on the branches of trees (different varieties of oak) the leaves of which serve as their food, but they must not be exposed to the sunlight. Too many eggs should not be placed on the same branch lest there be not enough leaves to feed the worms. At the same time, great care must be taken to ward off birds and insects which may devour the larvæ.

After the larvæ are hatched, from 45 to 50 days elapse before the cocoons are formed. According to the Chinese Government Bureau of Economic Information, the eggs have been introduced into Japan, but there is no regular exportation of them.

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FRIDAY, SEPTEMBER 28, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICE.

NEXT WEEK.

A meeting of the Society will be held on WEDNESDAY, OCTOBER 3rd, at 8 p.m., when a paper on "Cinematography for Amateurs" will be read by DR. C. E. KENNETH MEES, Research Laboratory, Eastman Kodak Company. The chair will be taken by MR. GEORGE E. BROWN, F.I.C., Editor of the *British Journal of Photography*.

PROCEEDINGS OF THE SOCIETY.

HOWARD LECTURES.

DEVELOPMENT OF THE STEAM TURBINE.

By STANLEY S. COOK, B.A., M.I.N.A., M.I.M. (Parsons Marine Turbine Co.)

LECTURE III.—*Delivered 14th May, 1923*.

Synopsis.

Application of mechanical gearing to land turbines.
Geared turbo-generators.
Geared turbines for mill driving.
Direct coupled turbo alternators.
Construction of rotors.
Ventilation of stators.
Latest improvements in economy of turbines by re-heating and cascade feed-heating.

The successful application of mechanical gearing to marine propulsion opened up similar possibilities of improvement in land installations for certain purposes, wherever there was conflict between the economical speeds of the turbine and of the machinery it was employed to drive: the use of mechanical gearing in such cases has led to improvements in overall efficiency, reduction in size and cost of plant, and a considerable extension of the field of utility of the turbine.

For turbines of small power efficiency demands high speeds of rotation, such as from 5,000 to 10,000 revolutions per minute. The frequency of alternators is most commonly 50 cycles per second, giving a maximum speed of rotation with a two-pole field of 3,000 revolutions per minute. Gearing permits the two to be reconciled, and the turbine to be designed most economically as regards size, cost and efficiency. Even for larger alternators, when, as is sometimes the case, the frequency is low, say, 25 cycles per second, the maximum speed of rotation of the alternator, viz., 1,500, is too low for an economical design of turbine. So, generally speaking, gearing is now adopted for all small alternators, and for large alternators up to about 10,000 K.W. output when the frequency of supply is low.

For continuous current dynamos, the problem of commutation imposed severe restrictions on the output and speed and introduced difficulties of mechanical construction, when they were directly coupled to their turbines. Direct-driven turbo-dynamos have been built, with an output of 1,250 KW, at 440 volts and 1,500 revolutions per minute, but these may be taken as representing a limit of achievement by careful design and some compromise of efficiency. On the other hand, an output of 3,000 KW at 500 volts, with a geared dynamo at 300 revolutions per minute, and the turbine at 3,000 revolutions was found a simple proposition. By the use of gearing, the design of such dynamos has been set free from conditions which previously hampered the designer, and limited both output and efficiency.

Figure 27 gives an interesting comparison of designs for turbo-dynamos of 200 KW capacity, with and without gearing. A noticeable feature is the large reduction in the length of the commutator and in the length of the armature body.

In 1909, contemporary with the experimental installation of single reduction gears on the s.s. "Vespasian," a steam turbine of 750 B.H.P., at 2,000 r.p.m., driving a steel plate rolling mill at 70 r.p.m. through double-reduction gearing, was being built

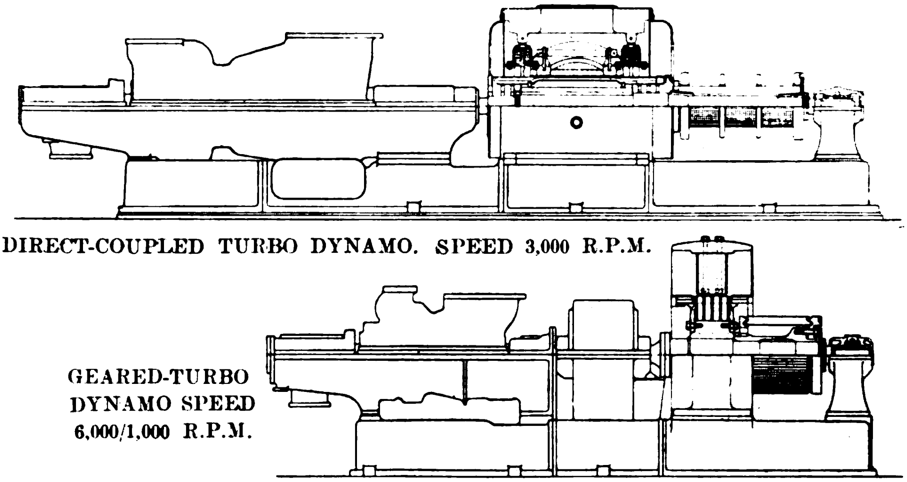


FIG. 27.

at the Parsons land turbine works at Heaton. This plant was installed at the works of Messrs. Dunlop & Co., at Calderbank, and has been a successful pioneer of land turbine reduction gears.

The success of this first installation led to the gradual development of such gears in land turbine practice. For most purposes single reduction is sufficient. Thus, in 1913, a 750 KW continuous current turbo-dynamo was installed at the Westminster Electric Supply Corporation's station in London, the turbine running at 3,000 r.p.m., and the dynamo at 300 r.p.m.

In the same year, a 4,500 KW geared continuous current generator set was installed at the St. Helens Glass Works of Messrs. Pilkington Bros. It had high pressure and low pressure turbines placed side by side—each driving a pinion geared to a wheel on the low speed shaft—an arrangement similar to that adopted in marine practice. The turbines ran at 2,400 revolutions per minute, and the three dynamos, each of 1,500 KW., which were coupled in tandem on the low speed shaft, ran at 370 revolutions per minute. This set is still in every day operation. Two additional sets, each of 4,500 KW output, recently installed in the same station, are designed on exactly the same lines, but embody modern improvements, such as increased K, greater use of end tightened blading, and pivoted thrust blocks.

In 1920, a second direct-current geared plant was installed at the Westminster power station just referred to, with an output of 3,000 KW from a single dynamo.

The increased output per dynamo which gearing has made possible, as in the last two examples, should be of great value for the development of high tension continuous current supply on the Thury system, if this again came to be considered practical politics.

The geared turbine has also come to be largely used in paper and textile mills in which the various machines are usually driven from a main shaft by means of ropes conveying power to each floor of the mill. In this case, the turbine replaces the low speed mill engine, and drives the main rope pulley through single reduction mechanical gearing, any further reduction in revolutions being made by means of the ropes in the usual way.

The geared turbine drive now enables the steam turbine to operate with good economy even for quite small outputs, and is widely used, in addition to the cases mentioned above, for driving centrifugal water pumps, small alternators, and the auxiliaries for the condensing plant of steam power installations.

An interesting example of versatility of service is the "pass-out" turbine. In many factories and works, such as paper mills, sugar refineries, distilleries and chemical works, steam is required for digesting, boiling and heating, in the various processes concerned with the manufacture of their products, as well as for the production of power. Large quantities of steam are sometimes required for such purposes at low pressure, and may first be utilised in a turbine exhausting at that pressure. But where the steam required for heating and process work is less than

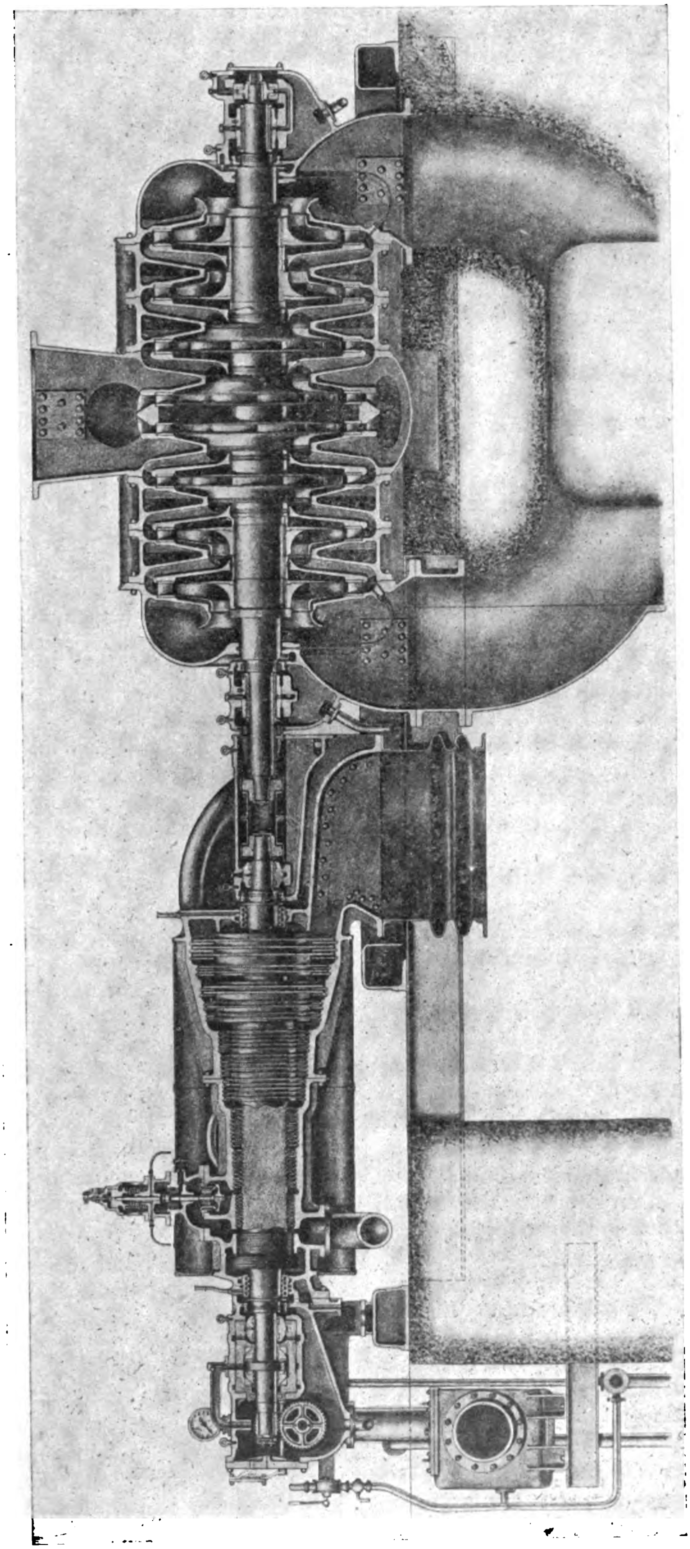


FIG. 28.

that required for power production, it can readily be taken from the turbine at a suitable point on the expansion range. Variation, however, of the output of the turbine, and of the demand for such low pressure steam from time to time, would cause considerable fluctuations in its pressure. It is, therefore, arranged to pass out all the steam from the turbine, and to pass back what is not required through a relief valve to lower stages of the blading, where its expansion is continued down to condenser pressure.

The direct-coupled turbine still, however, finds wide application for the driving of high power alternators which can now be built to run as fast as the turbines, at speeds of revolution limited only by the periodicity at which the electric current has to be supplied. The demand for large unit turbo-driven alternators has in recent years been so great that the total horsepower of turbines constructed for land purposes has now equalled that of marine turbines referred to in the preceding lectures.

Also in blowers and compressors for mining and metallurgical wirk, the general similarity between the physical properties of the propelling agent, steam, and the gas or air which is to be compressed, lead, naturally, to a similarity in the best speeds of rotation of turbine and blower or compressor, and in such cases direct coupling is perfectly satisfactory. A modern plant with a blower of the centrifugal type is illustrated in Figure 28. The turbine is of 2,750 B.H.P. at 3,470 revolutions per minute, and drives the blower direct. The normal duty of the latter is to deliver 40,000 cubic feet of free air per minute at a pressure of 14.0 per sq. in. gauge. This plant was installed in 1921 by the Indian Iron and Steel Co., Ltd.

In electrical power station work the great economy to be derived from the use of large steam turbines has stimulated the development of high speed alternators, of the largest size, for coupling to such turbines, and the development of the alternator has in its turn created a demand for turbines of large output. It will, therefore, not be inappropriate at this stage to make a brief reference to the most recent progress in alternator construction.

The more notable features of the development are the large increase in output at the higher speeds, and increase in reliability. Where, in 1909, a machine of 1,250 K.V.A. capacity at 3,000 r.p.m. was considered to be large, machines of 20,000 K.V.A., running at 3,000 r.p.m., have been manufactured, and machines of 25,000 K.V.A. at this speed are under construction. An alternator of 40,000 K.V.A. capacity, running at 1,800 r.p.m., is also under construction.

Early turbo alternators were built on the same principles as continuous current generators, the chief difference being in the end connections, which were led out to slip rings instead of to a commutator. Alternators with revolving armatures were made up to a size of 1,000 KW at 4,000 volts. With increasing size, the difficulties of manufacture and insulation soon led to this type being discarded in favour of the revolving field, the complexities of high voltage installation and end windings being thus confined to the stator, which is free from centrifugal stresses. Two types of revolving field were at first favoured, the salient pole type with two or more pole pieces each surrounded by its winding, and the barrel type with no poles externally distinguishable, but with conductors wound in slots in such a way as to produce polarity at suitable parts of the periphery. With increasing size the latter has proved itself the fitter to survive. A greater output can be obtained on the same periphery, with the same limiting stress, because of the better mechanical support it affords to the windings.

The maximum safe peripheral speed of the salient pole rotors was found to be 230-240 feet per second, whereas in the non-salient pole type, with solid steel forgings, 400 feet per second is permissible; even peripheral speeds of 480 feet have been adopted, although at the present state of our knowledge of steel forgings this figure appears rather high. In a suitably designed machine, with a cylindrical rotor, a very nearly pure sine wave can be obtained for the voltage curve.

The first cylindrical rotors were built up of thin sheet steel plates in a similar manner to rotating armatures. A later development was the use of mild steel plates about two inches thick, built up on a spider, which was solid with the shaft.

It was only a step from the plate rotor to the single piece solid forgings. The chief attraction of the plate rotor was its comparatively low cost combined with a certain knowledge of the properties of the material from the centre to the periphery, and it

continues to find favour in America. A doubt was expressed by many engineers, when solid forgings were first proposed, as to the possibility of obtaining a large forging which would be sound in the centre. The forge masters have, however, risen to the occasion, and satisfactory forgings have been made from 4 feet to 4½ feet diameter, and 10 to 12 feet in length.

It is now customary, in the case of the larger forgings, to trepan a hole in the centre. The material which is removed is carefully weighed, and by this means the presence of blow holes can be detected. The material is further examined microscopically, and subjected to chemical tests. The hole is examined for flaws, by a special arrangement of prisms and reflectors. Sufficient information is thus obtained to enable the forging to be accepted with confidence.

The most severely stressed part of a rotor is the cap which covers the end windings. These caps are now usually made of nickel chrome steel of high tensile strength.

The most important feature of an alternator's stator is the insulation of its windings. It may be said that the life of the machine depends upon that of the insulation. The essential qualities of an insulating material are, high dielectric strength, combined with flexibility. In earlier methods of manufacture, the insulation was moulded round the conductors, so as to form a hard compact tube, and this form, on account of its resemblance to a metallic structure, appealed to many engineers at the time. The disadvantage of the method lies in the fact that no allowance is made for relative expansion. The copper, having a higher coefficient of expansion than the insulation, and being at a higher temperature, has the greater expansion, and the tube must give way. In practice, cracks were found to develop in the insulation, which, consequently, failed under pressure test.

To overcome this difficulty, whilst retaining the method of moulding the insulating tube on to the conductors, either an insulation having the same co-efficient of expansion as copper, or a flexible insulation, must be used. A flexible insulation has been devised consisting mainly of mica, and is applied to the full length of the conductor in a special machine, capable of dealing with conductors from 5 lbs. to 3 cwts. in weight.

In order to eliminate eddy currents, it has become Messrs. C. A. Parsons & Company's practice to employ for stator conductors

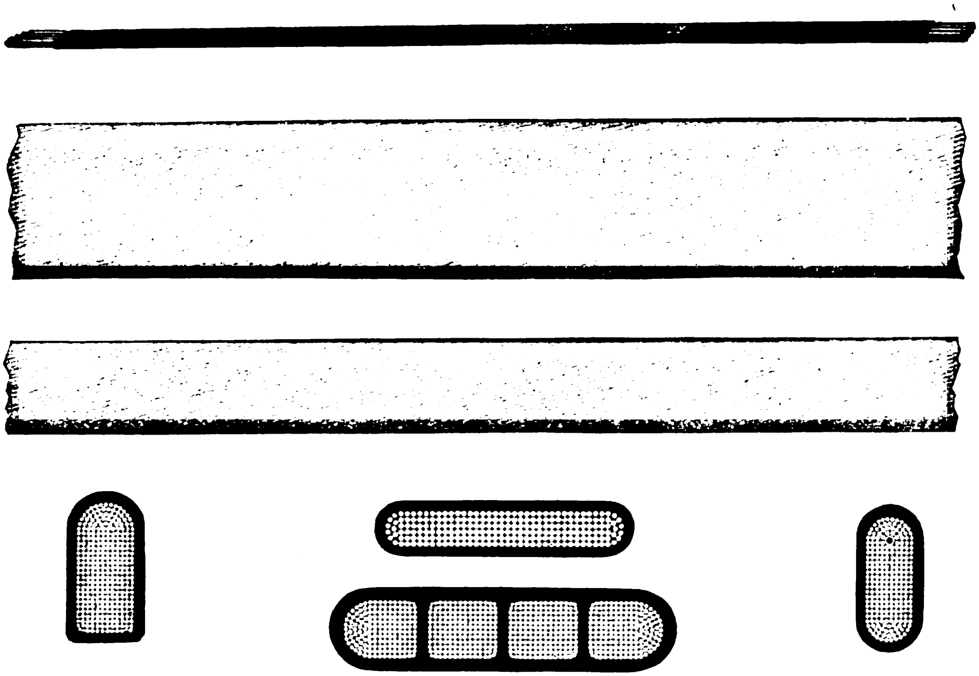
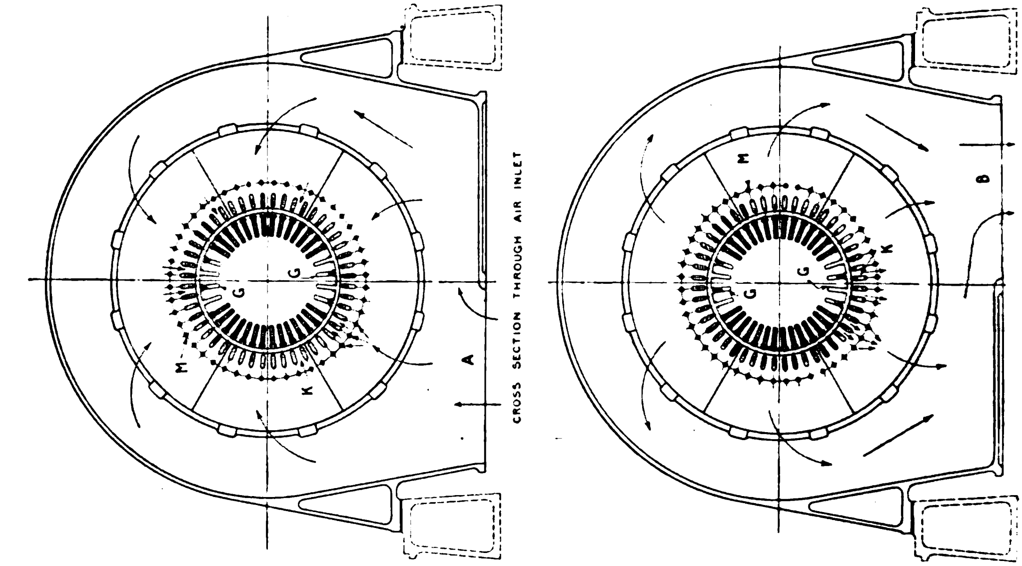


Fig. 29.

helically stranded cable with each wire separately insulated and spiralled ten or more times in the length of the conductor. Figure 29 shews examples of this stranded cable. This cable is constructed on a special cable making machine; it can be manufactured in any required shape without a central core and without crushing.

Whilst large alternators have thus been brought to a high state of efficiency, about three per cent. of the total output being sufficient to cover all the losses arising from windage, mechanical friction and electrical losses in the copper and iron of both rotor and stator, even this small percentage in an alternator of large output represents a considerable amount of heat. For example, in a 25,000 KW machine, three per cent. is 750 KW, or 2,500,000 British thermal units per hour, and effective means must be provided for removing this heat.



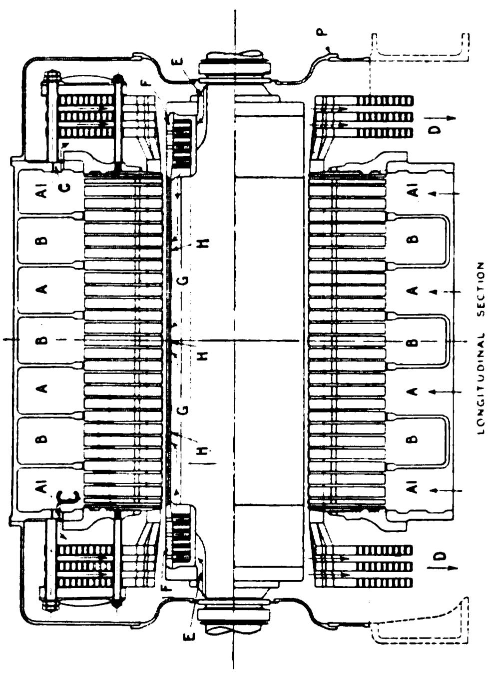


FIG. 30

The problem of ventilation is, therefore, an important one. With large sizes it has become more and more difficult to provide uniform cooling. In the older ventilation schemes, air is either drawn in or forced in from the ends of the machine, and the area available for the passage of air as it enters in this manner is restricted. Further the air is hot when it reaches the centre of the alternator, which becomes the hottest part of the machine. The output is, naturally, limited by the temperature of the hottest point.

Figure 30 illustrates a method which has been developed by Messrs. C. A. Parsons & Co., by means of which the alternator is uniformly cooled throughout its entire length. The alternator is divided throughout its length into several radial ventilation compartments forming parallel paths. Each alternate compartment "A" is a pressure duct from which the air enters the core, passes round the conductors and divides, passing axially along the air gap and back to the exhaust ducts "B" on either side.

A portion of the air is diverted through axial holes in the core situated behind the conductors. The quantities of air flowing in the parallel path are proportioned, so as to effect uniform cooling.

The stator end windings are ventilated from the end pressure compartments, "A1". Baffles are fitted to direct the path of the air in order to obtain the most effective cooling, with the elimination of local hot spots. The rotor is mainly surface cooled, but ventilation slots are provided in the poles.

In the earlier arrangements, the air was circulated on the open system (either as we have seen by fans mounted on the rotor, or by separate motor driven fans). This open system of ventilation is, however, subject to the disadvantage that dust from the air is deposited and accumulates on the windings. A filter is, therefore, necessary. Dry filters made of cloth have been used in some instances, but large areas of filter cloth were necessary, and the filter could not be cleaned without shutting down the unit. In one case, the filters took fire, with the result that the whole station was put out of commission. Dry filters were, therefore, superseded by wet filters, the air being passed through water spray, which removed the dust, and at the same time cooled the air below the temperature of the engine room. Here again, a disadvantage was found, in the danger of free moisture being carried into the windings. Serious short circuits have been caused in this way.

As the result of this experience with dry and wet filters, the open system has now been superseded by a closed circuit system of ventilation, in which the same air circulates continuously, and is cooled by water in a surface cooler. The cooler is made of a number of sections each consisting of a nest of tubes fitted with sheet iron gills.

This closed system, which was introduced in 1918, has several advantages. Contact of water with the air is avoided, the alternator is not subject to an accumulation of dust, since the same air is circulated through the system continuously, and in the event of fire, due to short circuit or other cause, the damage to the windings is limited, since the confined air quickly becomes incapable of supporting combustion.

The economic performance of a power unit is a matter in which boiler, turbine and alternator all participate. The turbine is often spoken of as a heat engine, but in reality, it is a hydro-dynamic engine, converting the pressure energy of the steam into work on the shaft. The real heat engine is the combination of boiler, superheater, turbine and condenser. When we have provided the highest efficiency of conversion in the turbine, and the highest efficiency of heat transmission in the boiler, there is still another link in the chain, the thermodynamic steam cycle, which alone determines the ratio between the heat supplied to the steam and the pressure energy available to the turbine. For further improvement in performance we must, therefore, explore the possibilities of the thermodynamic cycle.

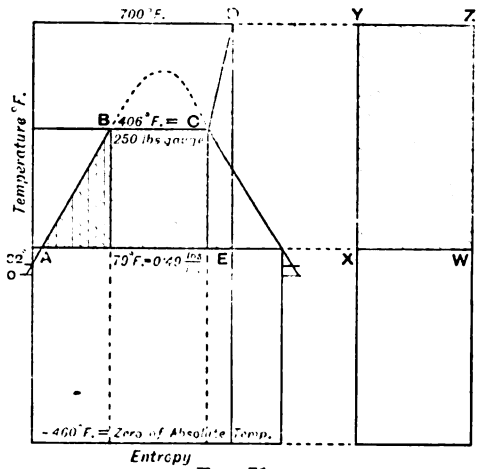


FIG. 31.

The diagram of Figure 31 represents the Clausius cycle for steam. It is a temperature entropy diagram, but all that one needs to know about the diagram is that vertical ordinates represent temperature, that any change of state of the steam can be represented by a curve joining two points of the diagram, and that the area down to the base line vertically below any such curve is proportional to the heat taken in or given out during that change. (All the properties usually associated with entropy, which is represented by the horizontal co-ordinate, follow from this definition.) For the cycle of operations connected with the turbine, we have first of all the curve AB, representing the raising of the feed water to boiler temperature, the line BC representing the generation of steam, horizontal, because evaporation takes place at constant temperature, and the rising curve

CD representing the superheating of the steam. No heat is taken in or given out during expansion in the turbine, so that the line which represents that process must be drawn so as to give no underlying area—it is therefore vertical. The vertical line DE thus represents expansion of the steam down to the temperature of the condenser. In the condenser, condensation takes place at constant temperature, and is, therefore, represented by a horizontal line EA, which completes the cycle. The area enclosed by the cycle ABCDEA, is the excess of the heat taken in from the boiler along ABCD, viz., the sum of the areas under AB, BC and CD, over that rejected into the condenser along EA, viz., the area under EA. This area therefore represents the energy which is converted into work, in a turbine which we are now supposing to be of 100 per cent. efficiency, because we are considering the energy presented to the turbine, which would all be converted into work if turbine efficiency were 100 per cent.

Now, we can see at a glance the shortcomings of this cycle if we compare it with another cycle XYZWX in which all the heat received from the source is taken in at the highest temperature along YZ, and that rejected is rejected at the lowest temperature along WX. Here the work done is represented by the area of the rectangle XYZW, whilst the heat taken in is represented by the larger rectangle from YX down to the base line. The proportion of the work done to the heat taken in is much higher than in the cycle ABCDE, and this is clearly seen to be due to the high temperature at which all the heat is taken in along YZ. The underlying areas of the first diagram shew us at once that, of the heat taken in along AB, that is, during the heating of the cold feed in the boiler, only a small percentage is converted into useful work. The heat taken in along BC, which is the latent heat of the steam, contributes a larger percentage, but still considerably less than the maximum. Even that received along CD during the process of superheating, yields less than the ideal maximum efficiency.

Improvements of efficiency through enlargement of this working cycle, by increase of steam pressure, increase of superheat and reduction of condenser pressure, were exemplified in the concluding portion of my second lecture. There are still two other ways in which the thermodynamic cycle may be improved.

The first of these consists in regenerative, or "Cascade" feed heating, by steam drawn from the turbine after it has been partly expanded. The steam is tapped off in stages, some at a moderate pressure, some at atmospheric pressure, and some at a low pressure, such steam being condensed by the feed water and raising the temperature of the feed water practically to its own temperature in each case.

If it were possible to use an infinite number of such stages, heating the feed water a few degrees in each stage, up to the boiler temperature, we can see from the diagram that the efficiency of that part of the cycle would be increased to the ideal maximum efficiency for saturated steam. For now no heat has been received from outside sources during feed heating; consequently, the heat represented by the area under AB has been saved; at the same time the work represented by the shaded area under this curve, has been lost. It is, in fact, the work lost due to the incomplete expansion of the tapped off steam. So that both as regards heat absorbed and work done, that part of the diagram may be considered as suppressed, and we are left with the more efficient portion of the cycle. As an example, with a steam pressure of 250 lbs. per square inch, absolute, and a vacuum of 29 inches, the suppression of this part of the diagram gives a theoretical increase in the efficiency of the cycle of 13 per cent. In practice, by cascade feed heating in *three* stages, a saving of about eight per cent. can be effected.

Cascade feed heating was first proposed by Ferranti in 1906. But feed heating in a single stage by partly expanded steam is a well-known expedient. With marine turbines, it is general practice to utilise the exhaust steam from the auxiliary engines, at a pressure slightly above atmospheric, for this purpose.

Again, on the other side of the diagram, it will be clear that the efficiency of the cycle can be increased by adding more heat at the higher temperature, and there we have the case, or part of the case, for superheating and for re-heating.

Curve A in Figure 32 shews the extent to which the efficiency of the thermodynamic-cycle is increased by superheating. But that is not all. When steam expands in a turbine, a certain amount of condensation takes place. The proportion of water of condensation in the steam gradually

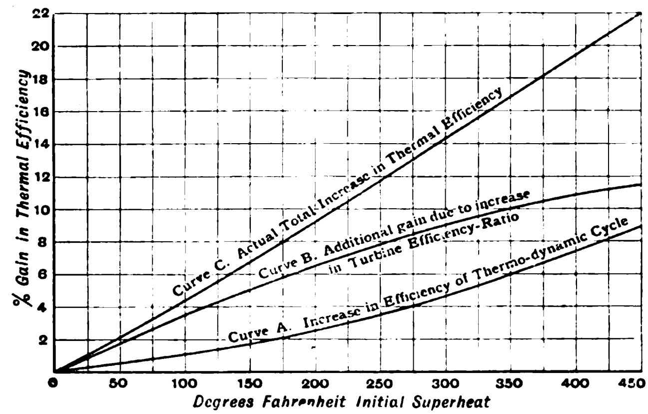


FIG. 32.

increases as the expansion proceeds. And we can no longer detach the efficiency of the turbine itself from our consideration of this question, because of the effect of the superheat in delaying such condensation, and so diminishing the amount of moisture present in the steam. Since this moisture results in a loss of turbine efficiency, the efficiency of the turbine itself is improved when we have superheat, quite apart from the improvement of the thermo-dynamic cycle efficiency.

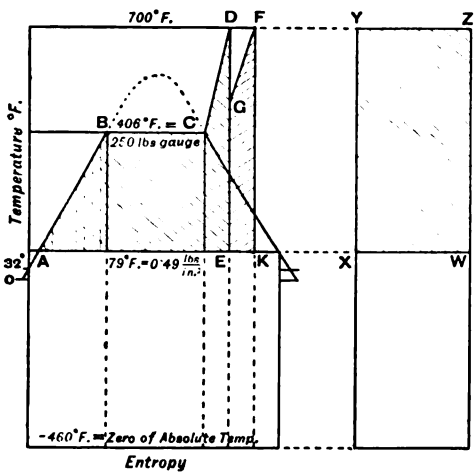


FIG. 33.

We thus have a second curve B representing the improvement in turbine efficiency resulting from superheat, and a third curve C representing the total gain from these two causes.

Figure 33 illustrates the case of reheat. After the steam has expanded to, say, the point G, it is reheated to the top temperature, and then allowed to continue its expansion. The result is the addition of the area GFKE to the diagram, and since here, along GF, heat is taken in at a temperature higher than the average temperature along ABCD, a gain in efficiency of the cycle results. But here, too, we have a far more important gain, as in the case of superheat, arising from the reduction of the moisture in the steam.

This process of re-heating might be repeated at various stages of the expansion, with advantage from a theoretical point of view. But a single reheat presents sufficient practical difficulty. The point at which the steam is taken from the turbine for reheat is a matter for most careful investigation to obtain the best results, and, not to enter into further detail, it is being chosen so that, after subsequent expansion, the steam will finish with only one or two per cent. of moisture of condensation.

The resulting gain of efficiency, which, as before, is a combination of improvement of thermodynamic-cycle efficiency and improvement of turbine efficiency through reduction of moisture, is estimated at about seven per cent.

These improvements in efficiency, viz., that due to cascade feed heating, and that due to reheating, are on the point of being realised. When they are realised, is there anything more we can do for our thermodynamic cycle ?

I venture to suggest that it would be well worth the attention of boiler manufacturers thoroughly to investigate the limits to which they can go in making boilers suitable for higher pressures and higher temperatures, by which the heat engine, of which the turbine is only a part, could be brought to a still higher plane of thermal efficiency.

The rise of the steam turbine is an historical event, the importance of which cannot well be exaggerated. Pioneered by Sir Charles Parsons, it has also been piloted by him through the most important phases of its development, which I have endeavoured to outline before you in these three short lectures. I have endeavoured to trace its progress in three directions, increase of efficiency, growth in size, and extension of utility.

During the period under review, in land turbines, the efficiency has been nearly doubled, in marine turbines, more than doubled. As regards output, the size of the unit has continued to grow until we are now well in sight of a capacity in a single unit of 100,000 H.P., and as regards utility, we have seen the turbine established for a large variety of purposes on land, and for practically all classes of vessel in that tremendous field of marine propulsion.

In conclusion, I desire to place on record my most grateful acknowledgments to Mr. R. Dowson and Mr. J. Rosen, of Messrs. C. A. Parsons & Co., for much generous assistance in the preparation of these lectures, particularly in that part which relates to land turbines and alternators; also to the firms of Messrs. C. A. Parsons & Co., and the Parsons Marine Steam Turbine Co., for information and facilities freely placed at my disposal.

For permission to reproduce Fig. 19, I am indebted to the courtesy of Sir Isaac Pitman & Sons, Ltd.

NOTES ON BOOKS.

Hunters of the Great North. By Vilhjalmur Stefansson. London: George G. Harrap and Co., Ltd. 7*s*. 6*d*. net.

In April last attention was drawn in these columns to a remarkable book by Mr. Stefansson, entitled "The Northward Course of Empire," in which he advocated the somewhat startling thesis that at no very distant date the world would have to look for its supplies of meat to the fertile prairies of the Arctic regions. Revolutionary as the idea seems at first to any one filled with the usual stereotyped notions of the ice-bound North, Mr. Stefansson brought forward reasons which demand the most careful consideration, and he also threw a flood of fresh light on the conditions of living within the Arctic Circle. The present volume gives further information regarding those conditions. The author, who has spent two winters and thirteen summers in the Arctic, describes how he learnt to live as an Eskimo, feeding for months on end on nothing but fish, raw or boiled; dwelling in snow-huts, which he was taught to build himself; hunting seals, polar bears, caribou and other Arctic game with his Eskimo friends; and making long journeys by land and water either in their company or entirely alone.

Mr. Stefansson set himself deliberately to enter as closely as possible into the life, both physical and mental, of the Eskimo, and he has a great deal to tell about them which will, we think, be new to nearly all his readers. Here, for instance, is a curious picture of life in the frozen North: "Nothing was more interesting than the way they dealt with the extreme heat of the cooking-time in the afternoon. As I have said, the temperature sometimes rose above 100°. On coming into the house we took off all our clothes except knee-breeches, so that everyone was stripped from the waist up and from the knees down. The children up to the age of six or seven were entirely naked. One of the occupations of the men was to sit for hours cutting soft shavings from blocks of beautiful white spruce driftwood. These shavings were put in great piles in the corners and into bags and boxes. Because of the extreme heat there were streams of perspiration running down the faces and bodies of most of the people. . . . Those who perspired most would take a handful of shavings, rub themselves with it towel-fashion, and then throw each handful away. . . . . Not really to get relief from the heat, but rather for pleasant stimulation (as we take cold showers after a Turkish bath), one or another of the perspiring people would run out and stand for a few minutes outdoors, naked except for the knee-breeches."

The Eskimo has found out how to keep warm not only in his snow-house but also in the open air with a temperature of 40° below zero. Mr. Stefansson gives a full description of the clothing which he wears, the way it is prepared, and the simple means by which it can be adjusted to suit varying temperatures. With Eskimo clothing intense cold and even blizzards lose their terrors, and life becomes enjoyable at exceedingly low temperatures.

Among many of one's preconceived notions which the author shows to be wrong, is the theory that a beard protects the face in hard weather. "The Eskimos told me that this was the opposite of the truth, and it was partly thoughtlessness that I did not take their advice and shave clean for this journey. As it was I had a full beard. Had the weather been a little colder the condition might not have been quite so bad. I think the temperature was about 10° below zero and the wind perhaps forty miles an hour directly against us. The snow that struck my face melted in part, and the water ran down my cheeks, freezing in the beard. This helped to cake the snow into the beard. I tried at first to keep my face clear by taking off my mittens and melting some of the ice off with my

hands, but I soon concluded that if I continued this my hands would freeze. Hands are worth a great deal more than faces, especially in the North, and so I kept them warm in my mittens, allowing my face to freeze. At first I kept both eyes open by clearing them occasionally with one of my hands, but even this seemed a little risky, so I closed one eye and allowed the ice to form over it." When the author reached the end of his journey his face was covered with a mask of ice weighing about ten pounds. After that experience he never wore a beard in cold weather.

Mr. Stefansson knows as much about the Arctic regions as anyone living; his powers of observation are original and fresh; and he has produced a volume which should afford delight to any one anxious to obtain an insight into the life of a people whose habits and environments are so remote from our own.

OBITUARY.

WILLIAM JOHN LEONARD.—Mr. W. J. Leonard was the senior partner in the firm of Messrs. Carless, Capel and Leonard, Petroleum Distillers and Refiners, of Hope Chemical Works, Hackney Wick, E.9., and had been in the Petroleum Industry for over fifty years. One of the pioneers of the Automobile movement, he was a founder member of the Automobile Club, which subsequently became the Royal Automobile Club. From the beginning he was a firm believer in the future of the motor car, and introduced the first spirit used in motor cars which he called "Petrol." This spirit is still being manufactured to-day. When the Locomotives Act of 1896 was passed, which for the first time legalised the use of motors on the highways in this country, he induced the railway companies to carry motor spirit at reasonable rates. Since then he was actively interested in the questions of transport and storage of inflammable liquids. He gave evidence for the London Chamber of Commerce, and the Select Parliamentary Committee on Petroleum. He served on the Committee of the R.A.C., and the Committee of the London Section of the Society of Chemical Industry. He was elected a Fellow of the Royal Society of Arts in 1903, and contributed the sum of £100 to the fund for purchasing the Society's House.

YUCATAN LABOUR COSTS IN SISAL PRODUCTION.

Mr. G. A. Lowry, Member of the American Society of Mechanical Engineers, sends the following details in the hope that they may prove useful to those who contemplate taking up the production of sisal fibre :—

In the establishing of plantations and decorticating plants for the production of tropical fibres, the items of expense which should be most carefully studied are those of the supply and cost of labour.

As a rule lands for the growing of the plants can be had for a merely nominal sum, but labour is not always available. There are several decorticating plants now eaten with rust in countries where sisal grows abundantly but where labour could not be had.

Taking the area of the country and dividing it into the estimated population is not a safe guide, as most of the people are near the large rivers which form the arteries of the country, while the arid districts are, as a rule, nearly devoid of inhabitants. I personally know of sections in South America in which there are several hundred thousand acres of wild sisal, but in which there is no labour to be had at a price that would pay to cut it.

As Yucatan is the main factor in the sisal market, the following carefully itemised costs of production should be a basis from which to figure for competitive production.

Twelve bales of fibre weighing 5,073 lbs. Plant operated three days to produce same.

				U.S. Money.
Cutting 100,000 leaves @ 20 cents per 1000 leaves				$20.00
Transportation to mill	@	3	cents	$3.00
1—chief rasper ..	@	½	,,	$.50
2—Ass't raspers ..	@	⅝	,,	$.63
1—receiver of fibre	@	⅜	,,	.37½
1—receiver of pulp	@	⅜	,,	$.37½
1—spreader of pulp	@	⅜	,,	$.37½
3—elevators of leaves	@	⅜	,,	$1.12½
3—pulp men ..	@	⅜	,,	$1.12½
6—hangers of fibre	@	⅜	,,	$2.25
3—collectors of fibre	@	⅜	,,	$1.12½
2—balers @ 12½c. per bale—12 bales				$3.00
2—rope makers @ c.5 per rope—12 ropes				$1.20
1—transportation of bales of railway				$.30
3—laborers @ $.37½ per day—3 days				$3.37½
1—stableman $.37½ per day—3 days				$1.12½
1—Ass't engineer @ $.62½—3 days				$1.87½
1—roustabout @ $.40—3 days				$1.20
2—watchmen—3 days ..				$2.25
Necessary clearing 3 days				$12.50

150 liters of fuel oil @ $.10 per liter	$15.00
Oil for machinery	$2.50
75 kilos of corn for mules	$5.25
1—man in charge of plantation—3 days	$6.50
1—mechanic—3 days	$5.25
1—administrator—3 days	$13.00
Sundry small expenses	$7.50
Repair of machinery	$17.50
Freight to seaport	$6.90
Taxes, State and federal	$25.88½
Storage and dockage	$13.80½
Interest on capital $125,000.00 @ 6%—3 days	$60.00
Machinery, plant & operation	
	$237.79½

NOTE.—Cost f.o.b. shipping port $4.69 per one hundred lbs. Nothing has been allowed for value of the leaves.

It may be noted that the wages paid the Indians are barely a living wage, and I doubt if as low a rate prevails in any of the other American States.

G. A. LOWRY.

ECONOMIC DEVELOPMENTS IN CHOSEN (KOREA).

A report on economic developments in Korea has been prepared by the United States Trade Commissioner at Tokio, of which the following is a summary:—

The economic future of Chosen at this time seems in doubt. Originally Japan intended to maintain this possession as a source of raw materials, which would feed the industries of Japan proper. During the war, however, Chosen was in some measure industrialised. The success of the experiment is not yet established, partly because of the difficulties of adapting the Korean worker to industrial pursuits. Furthermore, while Japan was able during the war to absorb high manufacturing costs in Chosen, the situation is somewhat different now, and it is a question whether the industries of Chosen can survive foreign competition.

The population of Chosen is 17,289,000, of which 16,916,000 are native Koreans and 348,000 are Japanese. The Koreans are an agricultural people, 87 per cent being engaged in agricultural pursuits, and only 2¼ per cent being engaged in industry. All the pioneer work of developing industry and increasing agricultural productivity is in the hands of the Japanese, fully 80 per cent. of the Japanese population of Chosen being engaged in public service, trade, and general industry. The progressive business is conducted by the Japanese and their settlements, in a measure, determine the opportunities for trade.

It is only since 1910, the date of annexation by Japan, that it has become evident that Korea offers real opportunities for trade development. Since 1911, with the single exception of 1919, Japan has granted yearly subsidies to Chosen in amounts varying from 10,000,000 to 13,000,000 yen (1 yen = 2s. 0½d.). In spite of this assistance the Chosen national debt is increasing year by year. The government is, therefore, restricting all activities other than those deemed absolutely essential, and it is unlikely that any large programme for building or for the development of resources will be undertaken for several years.

The Koreans being essentially farmers, developments along agricultural lines have met with some degree of success. Experimental farms have been established, and Korean farmers have been encouraged to adopt improved methods leading to greater productivity. Under this stimulus the cultivation of rice increased from 3,314,352 acres in 1910 to 3,800,000 in 1920. Cotton production increased from 31,306,449 pounds in 1910 to 157,252,844 pounds in 1920. The cultivation of hemp has been popularised by the government, production figures increasing from 14,389,000 pounds in 1910 to 39,034,000 pounds in 1919. Efforts have been made to increase the supply of cocoons and raw-silk production. The quality of the silk is not sufficiently good for export, and the entire output is used for domestic consumption. Cultivation of the sugar beet has been encouraged since 1912. Stock raising has been popular in Chosen. At present the government is making an attempt to promote the rearing of animals. Improvements are also being made in tanning methods, which, in turn, increase the value of hides.

The Japanese have adopted a policy of reforestation in Chosen. Nurseries are maintained in the Yalu Forest, and new trees are planted immediately after the old ones are felled.

The Japanese are engaged in developing operations in copper, coal, and ore mining, and in iron manufactures. The value of the iron-ore production increased from £42,000 in 1910 to £400,000 in 1920, while coal production was valued at £39,000 in 1910 and £391,000 in 1920. Anthracite coal is found in large quantities near Pyengyang, where a mine is operated by the government. This coal is unsuited for industrial purposes. It is largely dust, and 90 per cent. of it is moulded into briquettes for the use of the Japanese Navy.

The production of raw cotton, hemp, flax, and raw silk has given ample opportunity for many years for the improvement and enlargement of the weaving and spinning industries. However, the lack of modern machinery and of skilled labour prevents manufactures of good quality. Production of all textiles in 1911 was 5,500,000 pieces, valued at £500,000, while in 1919 the production was 7,600,000 pieces, valued at £3,400,000.

The real progress in manufactures has been since 1914. With the war boom came the iron

foundries, the paper and pulp mill, sugar refineries, flour mills, and match factories. The end of the war and its reaction resulted in the closing of some of these mills. The revival will be slow, for their products were as much for export as for home consumption, and these products of Chosen are unable to compete in foreign markets. Whereas the total industrial production of Chosen in 1911 was valued at approximately £3,000,000, in 1919 the value was placed at £23,000,000—an increase of 760 per cent for the period of nine years. It appears that there is still a great incentive to accomplish further industrial development during the coming decade. However, because of financial stringency, it is certain that the rate of progress will show a decline in the immediate years.

There is no lack of banking facilities in Chosen. The Bank of Chosen was established in 1909 as the central bank. It is not only the bank of issue, but is also an exchange bank. It has its own branches in America, China, and Japan, and is financially able to undertake any transactions related to the trade and commerce of the country. The Chosen Industrial Bank is an amalgamation of a number of agricultural and industrial banks, whose chief function is to supply credit for the development of agriculture and industry.

Chosen has no labour problem, as have the more advanced industrial countries; but although labour is cheap, it is lacking in technical skill.

Its natural resources and the fact that it is a connecting link between Asiatic Russia and China and Japan are assets of considerable importance.

THE JAPANESE WOOLLEN INDUSTRY.

The Japanese market is of so much importance to British woollen manufacturers that the following particulars regarding the Japanese woollen industry, taken from the recently issued report by Sir E. F. Crowe, C.M.G., Commercial Counsellor to H.M. Embassy at Tokio, may be of interest and will serve to show how much progress is being made.

Besides the Government woollen mill there are several private companies spinning and manufacturing woollens and worsteds in Japan. Of these the Nippon Keori Kaisha (Japan Woollen Company) is the largest, although it is closely followed by its chief rival, the Tokio Keori Kaisha. The Nippon company has four mills at Kakogawa, Gifu, Innami and Himeji and it is continually expanding, the directors having thought it advisable to make their extensions in good time, so that when the new Factory Law comes into full force in 1925 or 1926, with the result that night work for females is prohibited, they will not have to reduce their output.

Their worsted plant consists of 63 cards, 8 Nobel Combs and 114 Continental Combs, 55,800 mule spindles and 16,600 ring and cap spindles, while they are installing the following new plant; 16 cards, 36 Continental combs, 18,900 mule spindles and 2,400 ring spindles.

The woollen plant consists of 65 cards and 32,640 mule spindles.

They have 771 broad looms and 972 narrow looms.

The number of operatives is 10,000, of whom 60 per cent. are females and the wages average Y1.15 for females and Y2.10 for males per day. [The normal value of the yen is 22.04½d.]

Another very interesting mill is that of the Goto Keori Kaisha. Mr. Goto is the pioneer of the wool industry in Japan and has been interested in it for 50 years. By the end of this year his company will have 12 sets of worsted cards, 16 Nobel Combs, 12,000 spinning spindles, 4,000 twisting spindles, 7 sets woollen cards, 3,000 woollen mule spindles and 600 looms. British machinery for an alpaca plant, the first of its kind in Japan, is now being installed. Further extensions are contemplated by 1925. This mill is situated at Gifu, and it is surprising to find that the female labour is paid on the average higher than male, the following being the rates for women: spinning Y1.25 a day, combing, Y1.50, gilling and drawing Y1.25, and reeling Y1.50. Male labour can be obtained at only a little over Y1 a day.

It must be remembered, however, that in addition to the wages, the company—and this applies to nearly all textile companies—pays part of the cost of board and lodging. The proportion varies in the case of different companies, but, roughly speaking it amounts to from one-half to two-thirds. That is to say, that it is estimated that the cost of a girl's board and lodging is about 30 sen a day and the company charges her from 9 sen to 15 sen. (100 sen equal 1 Yen.) There has been a very great improvement of recent years in the conditions in the textile mills in Japan, and it is important to emphasize this because so many people still imagine that the conditions which prevailed ten to fifteen years ago hold good to-day. The change has partly been brought about by humanitarian considerations, but chiefly because the mills have found it increasingly difficult to get the necessary labour, and girls refused to come to mills where conditions were bad.

The following is a very short description of conditions in a modern factory which was visited recently:

The dormitories are in two-storied wooden buildings containing 36 rooms. Each room has 18 mats—(the area of a room in Japan is always calculated by mats—each mat measuring 6 feet by 3 feet, and accommodates 10 girls.) In the old days the proportion used to be about 24 girls for a 12 mat room as the day shift moved in to sleep as soon as the night shift had moved out. All this has been changed. The company provide free of charge the "futon" or Japanese sleeping mattresses and quilts and the mosquito nets. The rooms are well lit by electric light and steam heated: there are wide corridors running the whole length of the building and each girl has a small cupboard under lock and key for her own belongings. There is a very large bedroom with hot water where the girls can have one or two baths a day. The dining

hall is a large room with tables and proper chairs—instead of the miserable benches which used to be provided. The food is substantial, but to an European not very appetising. Three meals a day are served consisting chiefly of rice, soup and vegetables. Meat is given once a week and fish twice a week. There is a large 120 mat room for entertainments. A well-equipped hospital and a special isolation ward are in buildings close by. In the dormitories the paper windows which are, as usual, a feature of Japanese houses, have all been replaced by glass, frosted as regards the lower panes so as to ensure privacy. The girls are free to go out once a week and they can receive visitors in rooms specially provided for them. There are three tennis courts, one basket ball ground, and the male operatives have a baseball ground.

It must not be supposed that the conditions described above are exceptional. Many other mills were visited and a very general improvement throughout was found, especially as regards facilities for sports and amusements.

There is one important point which will convey very clearly to persons who had experience of old-time Japanese mills how great an alteration has taken place. In former times the sanitary arrangements were most unsatisfactory. The farmers in the neighbourhood used to pay a considerable sum for the night soil which they used to cart away. Now the position has been changed and the farmer has to be paid to carry out the removal, and up-to-date mills are considering the adoption of septic tanks, but the movement is not yet general and there is probably an opening here for British sanitary engineers who could instal plant suitable for large millso ?from 500 to 2,000 hands.

NATIVE INDUSTRIES IN EGYPT.

Among the most widespread and successful of the native industries of Egypt, depending to a considerable extent on primitive equipment and tools, are weaving of cotton, wool, silk and linen fabrics; tanning and leather goods, dyeing, pottery for household use, ornamental brass, silver and copperware, jewellery and basket-making.

Although the weaving of all the above-mentioned fabrics is largely a "cottage" industry, carried on by means of thousands of hand-looms, the excellence of the finished product, says the British Commercial Agent in Egypt in his recent annual report, is in many cases as surprising as the variety of designs and kinds of articles that are turned out. Saddlery and leather goods, in particular, such as suitcases, trunks, attaché-cases, gun-cases, &c., are produced locally of such good quality and appearance as to compare very favourably with imported goods, although the raw material is mostly tanned entirely by manual processes.

Boots and shoes are largely made by hand, particularly the sandals and heel-less slippers that have so great a vogue among those of the poorer classes who cannot afford European boots or shoes, or whose calling renders them unsuitable and impracticable.

Rugs and carpets woven from both imported and locally produced wool, and combined with vegetable dyes, are produced in most attractive shapes and designs under the auspices of the Beduin Industries Amalgamation; but these articles are also produced by means of hand spindles and hand-looms, as a purely cottage industry, from sheep's wool, and goat and camel hair.

The dyeing industry in the villages, which colours fabrics in black and blue mostly, using natural indigo from India and synthetic indigo from Europe, is carried on by primitive methods, but the few dyers in Cairo and Alexandria, who have adopted up-to-date methods and use aniline dyes imported from abroad, are capable of producing an extensive range of colours and designs applied to locally-made fabrics of various materials.

Other industries which specialise in artistic and ornamental work are ivory and inlaid wood-work, decorated leather, and ornamental copper, brass and silver-ware and inlay.

Raw materials available locally render it easy for rope and string and articles fashioned from them to be made in Egypt in great variety; as also matting of all shapes, sizes, and designs, made from reeds that grow profusely; and baskets and osier work, such as chairs and tables, all of these being the result of purely manual labour.

Furniture and general wood-work is, like most of the foregoing, a widespread and important local industry employing some 50,000 hands.

Industries of comparatively recent date consist of the Tarbousch factory at Kaha, established in 1909, as the result of purely Egyptian enterprise. Its output varies with the fluctuation of foreign competition, which it finds difficult to combat at times owing to faulty methods of getting the finished article on to the Egyptian market, and to the fact that both the raw materials, *i.e.*, fabric and the dyes, have to be imported.

Bedsteads made of iron and brass are manufactured in one of the Cairo districts.

Glue making was inaugurated after the outbreak of the war owing to the high prices for, or difficulty of obtaining, the imported product, and there has been produced from raw materials available in Egypt a kind of glue which is stated to be equal to the best imported.

The manufacture of paints, &c., from mineral colouring materials available in the neighbourhood of Aswan is a recently established industry due to purely Egyptian enterprise and initiative. The factory erected at Helouan has now been completely equipped, and the promoters hope to increase their production, which amounted to only 430 m. tons in 1921 and 350 in 1922.

One of the most interesting features of the permanent exhibition of Egyptian arts and crafts, which is under the auspices of the Bureau of Commerce and Industry, Cairo, consists of the brass and copper-ware produced by Egyptian skilled labour for household and hospital use, such as geysers, hot-water fittings, appliances for sterilising surgical instruments, etc., whose general appearance, design and workmanship are good enough to stand comparison with all but the very best European manufacturers.

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FRIDAY, OCTOBER 5, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICE.

EXTRA MEETING.

WEDNESDAY, OCTOBER 3rd, 1923; MR. GEORGE E. BROWN, F.I.C., Editor of the *British Journal of Photography*, in the Chair.

A paper on "Amateur Cinematography" was read by DR. C. E. K. MEES, and a demonstration was given.

The paper and discussion will be published in a subsequent number of the *Journal.*

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

PRECISE LENGTH MEASUREMENTS.

By J. E. SEARS, JUNR., C.B.E., M.A., M.I.Mech.E., A.M.Inst.C.E.

Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards.

LECTURE I.—*Delivered March 5th,* 1923.

ON THE CONTROL OF BASIC STANDARDS.

In the series of lectures which I begin to-night, I propose to discuss and illustrate some of the more interesting facts, methods, and problems of present day metrology; to give an idea of the degree of accuracy now attainable in the control of various types of length standards, with the possible ines of development and the difficulties and the limitations attaching thereto, and, finally, to describe certain practical applications to every-day measurements. The field to be covered by such a survey is a very wide one, and I shall be forgiven if I touch only very briefly on certain aspects of it. Not that these are unimportant, but that they are matters of more common knowledge than the points with which I hope to deal.

The two principal primary standards of length in the world, the British Imperial standard yard, and the International prototype metre, are both material standards, and the provision made for their replacement, in the event of loss or damage, is, in each case, by reference to other similar bars with which respectively they have from time to time been most carefully compared. The Imperial standard yard and its copies (known as the Parliamentary copies) are bronze bars, made of Baily's metal, an alloy containing 16 parts of copper, $2\frac{1}{2}$ parts of tin, and 1 part of zinc. They are of 1-inch square section, 38 inches long, and one inch from either end, a round pit, $\frac{1}{2}$ inch diameter and $\frac{1}{2}$ inch deep, discloses the neutral plane of the bar. At the centre of each pit is a polished gold plug 1/10 inch in diameter, on which are traced the lines which serve to define the yard length. The object of sinking the graduation marks to the neutral plane of the bar is partly to minimise risk of damage. But more essentially it is to eliminate the effects of flexuro of the bar. If the graduations were on the upper surface any change in the position of the supporting rollers would have a marked influence on the apparent length of the bar. With the graduations in the neutral plane, if the positions of the supports are properly chosen, slight errors in setting them have negligible effect on the length. These bars, with the exception of one Parliamentary copy, which is deposited in the Standards Department of the Board of Trade, were all cast in 1845, and became legal standards in 1855. They have been intercompared at intervals ever since, and by the Weights and Measures Act, 1878, it is now required that all the Parliamentary copies, with the exception of one immured in the Houses of Parliament, shall be intercompared every ten years, and compared with the Imperial Standard itself every 20 years. It so happens that one of these comparisons has recently been completed, and as an indication of the accuracy attainable in the control of these bars, the subjoined table, showing the results of the successive comparisons, may be of interest.

TABLE I.

Comparisons.	Difference in millionths of an inch.						
	1922	1912	1902	1892	1886	1876	1853
P.C.2—No. 1 ..	−19	−23	(−24)	+6		+36	+21
P.C.3 No. 1 ..	−61	−49	(−96)	+55		+57	−33
P.C.5 No. 1 ..	−23	−43	(85)	+70		−33	−55
P.C.6—No. 1 ..	−217	−215	−192		−3		
P.C.4—No. 1 ..	−90						+7

It will be seen that the results of the 1922 comparisons in no case differ from those of 1912 by more than two hundred-thousandths of an inch, *i.e.*, about one part in two millions of the whole length of one yard.

Some of the intervening comparisons differ appreciably from these, but, with the exception of the immured standard, No. IV., which has a somewhat defective line at one end, and the Board of Trade copy, No. VI., which is a relatively new bar, cast in 1878 and first compared in 1886, it will be seen that the 1912 and 1922 results agree well with the original comparisons of 1853. These original comparisons were carried out with extreme thoroughness and care under the superintendence, first, of the Rev. R. Sheepshanks, and after his death, of the late Sir G. B. Airy, at that time Astronomer Royal. It cannot be pretended that the later comparisons have all been equally thorough, and this perhaps accounts for some of the variations observed from time to time in the relative lengths of the bars. The comparisons of 1912 and 1922, which agree so well with each other, and also with those of 1853, have been made upon a new comparator of much improved construction, designed by Dr. A. E. H. Tutton, and now installed at the Standards Department, 6, Old Palace Yard, Westminster. The comparisons of 1922, moreover, were probably the most complete ever undertaken since the original series, so that these results should be particularly reliable.

The method by which two standard bars are ordinarily compared is as follows. The bars are mounted side by side, one on each of two independent girders carried on a table which is provided with a traversing movement at right angles to their length. The graduation lines are observed by means of microscopes rigidly fixed in such a manner as to be unaffected by any movement of the weight of the traversing table. Each girder is provided with independent adjustments by means of which the bar can be moved through small distances either lengthwise, up and down, or sideways, so that each graduation mark can always be brought into correct focus in the centre of the field of view of its appropriate microscope. The microscopes are provided with double spider lines on a frame in the eyepiece, which is moved by means of a micrometer screw in a direction parallel to the length of the bar, and readings are taken by setting the pair of spider lines symmetrically with respect to the enlarged image of the graduation mark, and recording the indication of the micrometer drum. The value of a division of this drum has to be determined by previous calibration, an operation too long to describe here, but once this is known, the accurate determination of the difference in length between the two bars becomes mainly a question of careful and oft-repeated observations.

The question of temperature control is, of course, of the highest importance. The length of a bronze yard bar increases by nearly four ten-thousandths of an inch for every 1°F. increase in temperature, so that if an accuracy of one-hundred-thousandth of an inch is to be attained, it is necessary to know the temperature with certainty to 1/36°F. Allowing for other possible sources of error 1/100°F. must be aimed at.

In the comparator shown in Fig. 1, made by the Société Genevoise and similar to that used at the Bureau International, Sèvres, for the comparison of the national copies of the metre, the control of temperature is effected by means of a double water bath, the inner tank, containing the two bars, being filled with distilled water, while the outer tank may be filled with crushed ice, or with ordinary water at any temperature which it is desired to maintain. Each tank is independently stirred by means of small propellers driven by a motor, and the temperatures are read, after a steady state has been reached, by means of thermometers immersed in the water alongside the bars in the inner tank. In the case of the Tutton comparator (Fig. 2), used for the recent comparisons of the British standards, the bars are kept in air, the whole comparator being in a room maintained at a constant temperature by means of electric thermostats. Even so, it was found extremely difficult to maintain a sufficiently steady temperature in the wooden enclosure surrounding the bars, owing to the penetration of the bodily heat of the observers, and

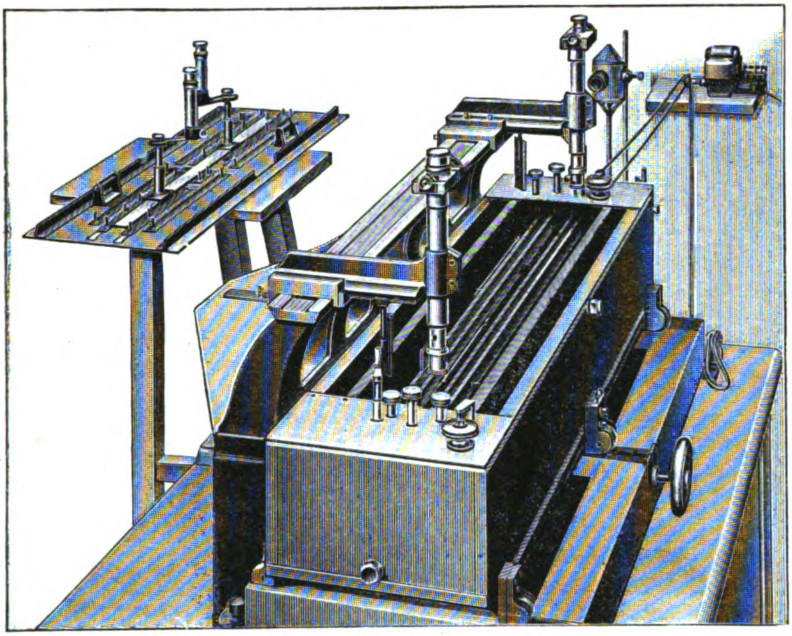

Fig. 1.

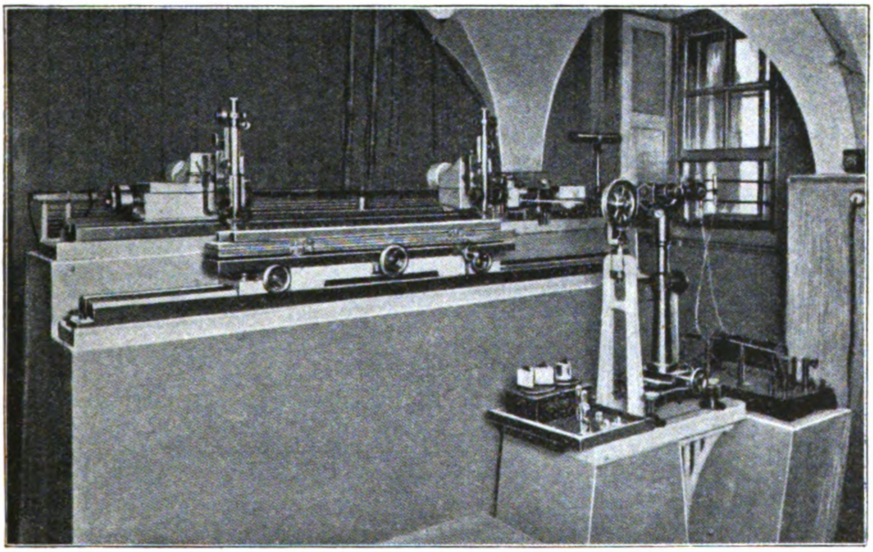

Fig. 2.

it was only by replacing the wooden covering by one of copper, interleaved with asbestos board, that satisfactory conditions were finally achieved.

The general principles underlying both comparators are identical, though the details of construction are very different. The Tutton comparator, moreover, is provided with special fittings, shown on the right of the illustration, enabling measurements to be made in terms of the wave lengths of light. This appliance is not required for ordinary comparison work, but the subject is one we shall have occasion to revert to later.

The actual course of a comparison is this. One of the two bars having been brought under the microscopes by traversing the table, and the graduation marks at either end brought into position and focussed,

readings are taken on the two micrometer drums and recorded. The table is then moved across, and the same repeated for the other bar, and so on alternately. Readings of the thermometers are taken at intervals, and care is taken to arrange the observations uniformly with regard to time elapsed, and in such a manner that the mean time of all the observations on each bar and on the thermometers is the same. In order to eliminate various small systematic errors this has to be repeated further with each bar in turn reversed end for end, and with the bars interchanged on the girders. In all there are eight separate configurations for the bars on the girders, but by suitable choice of these all the essential variations in arrangements can be obtained in four settings. It is found also that individual observers have personal peculiarities, and to obtain accurate results it is important that at least two observers should participate in the work, and that each of them should take an equal number of observations on each end of each bar with each microscope.

In the recent re-verification of the British standards, eight bars were compared, each against each, making 28 comparisons in all; each comparison was repeated four times with four different settings of the bars; and the comparison for each setting included eight separate observations on each bar, or 32 microscope readings—a grand total of 3584 readings. Four observers took part, the arrangements being such that each participated equally throughout. The bars were allowed at least five hours to take up the uniform temperature of the room after being handled during any interchange, and the temperature of the enclosure only changed on the average by about 1/50°F. during the whole course of any single set of observations.

The final values, computed by the theory of least squares from all the comparisons taken together, are those shown in Table I., and reverting to that table again now, I want to call attention particularly to the results obtained with the newer bar, P.C. VI. Since its first comparison in 1886, this bar has shortened, relative to the older bars, by two-ten-thousandths of an inch—or nearly six parts in one million. We have some evidence at least that the older bars have not been changing sensibly during the greater part of this period, for two determinations of the ratio of the lengths of the yard and the metre made, one in 1895 and the other last year, in connection with the decennial comparisons of the British Imperial standards, have led to results in agreement within one part in two million, *i.e.*, within the possible experimental error. The standard metre bars are of platinum-iridium, of X-shaped cross-section, with the plane of the neutral fibres exposed throughout the whole length, and the graduation marks on polished areas in this plane at the two ends. They are thus entirely different in character from the bronze yard bars, both in material and form, so that the constancy of ratio between the yard and the metre, though not conclusive, is evidence in favour of the constancy of both sets of bars.

Even the constancy of the metre, however, is not entirely above suspicion, for during some recent re-comparisons of a number of national copies of the metre at the Bureau International, Sèvres, certain differences appeared which, on the average, seemed to indicate that all these bars had shortened, relative to the International prototype, by about four parts in ten million. This result appeared so improbable that a new and very elaborate investigation was undertaken, with the result that it was eventually found that the intermediate bars in use at the Bureau had themselves *lengthened* by four parts in ten million, and that the remainder of the variations which had been observed were due to the use of slightly erroneous values for the co-efficients of thermal expansion of the various bars when calculating their lengths at 0°C. from observations made at or about room temperature—an explanation, by the way, which affords a most illuminating commentary on the value of the virtue claimed for the metric system on the ground that its standards are correct at the easily reproducible "scientific" temperature of 0°C., instead of at the convenient every-day working temperature of 62°F., adopted for the British standard. But apart from this, the fact that two bars of the series should change relatively to all the others, and both by the same amount so that the change went for many years undetected, is clearly most disquieting, and cannot but introduce a certain degree of doubt as to the absolute stability even of the majority. But the amount by which the yard bar P.C. VI. has changed in the 36 years since 1886, is ten or twelve times as great as the small

discrepancies we have just been discussing, and, while this change far exceeds the possible experimental error, there seems no reason at all to suppose that any change of similar magnitude can have occurred during the same period, either in the older yard bars or in the metre bars. On the other hand, it is by no means impossible that the Imperial standard yard itself, and all the older Parliamentary copies, which P.C. VI. was made to resemble as closely as possible, as regards both material and construction, had themselves changed between 1853 and 1886 by an amount equal to that subsequently observed in the case of P.C. VI. It will be noted that this latter bar has shown negligible change in the last ten years, and the original bars were, in 1886, already nearly as old as it is now.

If this supposition has any actual foundation in fact, it would follow that the Imperial standard yard is now about two-ten-thousandths of an inch shorter than it was when first created. Such an amount, from the point of view of present day metrology, is extremely large, and I have said enough, I think, to indicate clearly how difficult it is to feel absolute confidence in the secular constancy of any material standard, and how desirable it would be to find some ultimate standard of reference, reproducible at any time with any required degree of accuracy, by means of which the material standards, which are a practical necessity of every-day life, could be controlled.

There have been, from time to time, attempts to utilise so-called "natural" standards of length as a basis for reference, and many measures of length—the foot being a notable example—have names which in themselves give sufficient evidence of the persistence of this instinctive idea from the very earliest times. More recently we have the original definition of the metre as one ten-millionth part of the earth's polar quadrant, and again the British Act of Parliament of 1824, by which the standard yard then legalised was to be replaced if ever occasion arose, by reference to the length of the pendulum beating seconds in London. But in spite of the care with which the work was done, it was soon found that the uncertainty of the measurement of the earth's quadrant was far greater than that attaching to the comparison of two material standard bars, and the original abstract definition gave place almost immediately to the actual bar known as the Mètre des Archives, which became the national standard of France until the present International prototype metre, with its various copies, was constructed, with a precision which enabled the International Committee to declare, when adopting the new standard, that it did not differ from the Mètre des Archives by more than the possible experimental error of the comparison. And when, in 1834, the then British Imperial standards were destroyed in the fire of the Houses of Parliament, the Commission appointed to advise as to their restoration, reported that it was impossible to obtain so high an accuracy of reproduction by reference to the length of the seconds pendulum as by direct comparison with other bars which were known at one time or other to have been compared with the lost standard, and whose differences from it had been recorded.

The first practical suggestion as to a natural standard capable of reproduction, with sufficiently high precision to be suitable for use as a control on material standards, was due to Prof. A. A. Michelson, who worked out a plan for determining the length of the metre in terms of the wave-length of some particular kind of light, and who was invited by the International Committee to set up his apparatus and carry out the experiments at the International Bureau.

To appreciate the delicacy and accuracy of wave-length measurements, it is necessary to understand the phenomena on which they are based. It is known that the atoms or molecules of various substances, when heated to incandescence, are in a state of rapid and vigorous internal vibration; and just as a tuning fork gives out a definite note, whose pitch depends on the number of beats the fork makes in a second, and which is transmitted to the ear by means of a train of sound waves set up in the air, so the vibrating atom or molecule sets up trains of light waves in the æther, whose frequencies depend solely on the nature and structure of the molecule, and are, therefore, always the same, given suitable conditions, for molecules of the same material. The colour of the light emitted depends solely on the period of vibration, and thus corresponds to the pitch of the musical note emitted by the fork. The structure of most molecules is very complex, and the molecules of each substance have, therefore, as a rule, a great many different natural

periods of vibration, corresponding to various colours of light. For the same substance however, the colours emitted are always the same, and in the same proportionate intensity, so that each substance gives rise to a characteristic illumination which, if analysed, suffices to identify the source from which it originated.

The trains of waves are electro magnetic in character, but as a mechanical analogy, may be likened to the ripples formed when a stone is thrown into still water. They spread outwards in all directions from their source, and it is known that the velocity of propagation of the waves through the æther is constant, and independent both of the period and amplitude (or intensity) of the wave. Thus the length of a wave of any particular period must be constant, and it is this constant length of a particular light wave, derived from some particular kind of material, which has been used with such success as a natural standard of length.

To indicate how light waves may be employed for this purpose, we must consider their nature a little more closely. We may illustrate the disturbance of the æther at

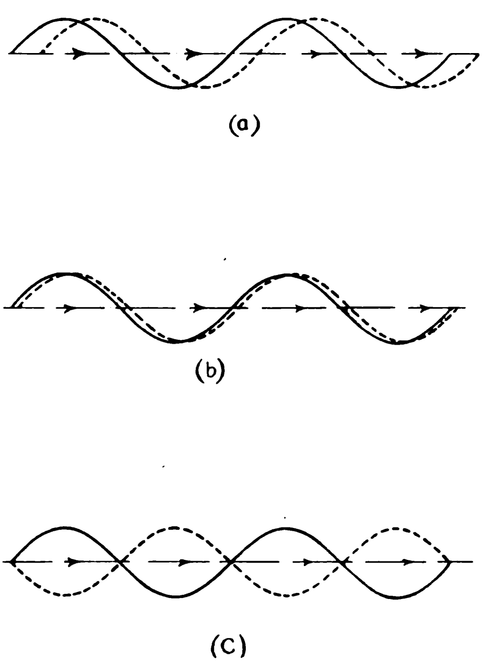

Fig. 3.

any moment, due to the passage of a single wave, by a simple sine curve as shewn in Fig. 3 (*a*).

At any subsequent moment the state will be represented by a precisely similar curve moved forward in the direction of the arrows by the distance which the wave advances during the time interval elapsed between the two moments considered. It will be noticed that every time the wave advances through a complete wave-length, the condition of affairs is precisely repeated. Now, suppose we have a second precisely similar wave travelling along the same path, but differing in phase from the first, such a wave would be represented by the dotted line in the figure. The nett disturbance in the æther, due to the simultaneous presence of the two waves, will be represented by the algebraic sum of the ordinates of the two curves, from which it is easy to see that if the two waves are out of phase by half a wave-length as at Fig. 3 (*c*), there will be no disturbance of the æther at all, and therefore complete extinction of light, whereas, if they are in phase, or differ in phase only by some whole multiple of a wave-length as shewn approximately at Fig. 3 (*b*), their effects will be added, and there will be brilliant illumination.

The most direct and simple way of comparing the length of a light wave with an ordinary standard of length is through the agency of a diffraction grating. This consists of a plane or concave surface, either of glass or metal, on which have been ruled, by means of a very special and delicate engine, a large number of exactly equidistant lines. Fig. 4 shows the engine used for this purpose at the National Physical Laboratory, which was originally constructed by the late Lord

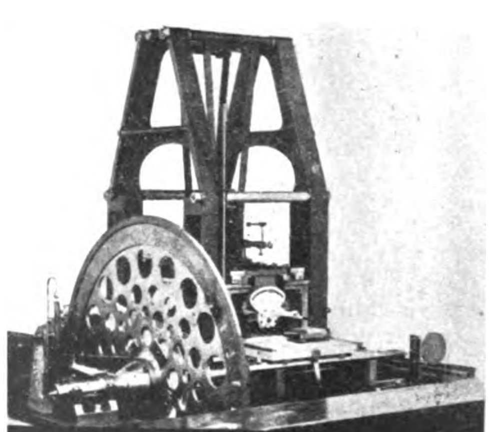

Fig. 4.

Blythswood, and since his death has been deposited at the Laboratory for safe custody. The plate to be ruled is placed on a carriage which can be traversed by means of a specially accurate screw. This screw has 20 threads per inch and is operated by means of a pawl and ratchet wheel, the latter having 720 teeth in its periphery. Each movement of the pawl, therefore, advances the carriage, and with it the plate, through 1/14,000 inch. While the carriage is at rest between the successive actions of the pawl, a fine diamond point is drawn gently across the plate and rules a line upon it, after which the diamond is lifted clear and returns ready for the next stroke during the time that the carriage is being advanced by the pawl.

The construction of the machine is very elaborate, as the minutest errors in spacing may seriously affect the final result. In particular it is necessary to guard against any periodic error in spacing which may be produced by the abutment of the screw, and this is achieved, on the engine in question, by putting a hardened flat polished facing on the end of the screw and adjusting this by an auto-collimating method until it is found to be as closely perpendicular as possible to the axis of the screw. This plane facing then bears on a polished spherical facing adjusted so that the centre of the sphere is accurately located on the axis of the screw. If either of these two adjustments could be absolutely perfect there would be no periodic error. But in practice it is found that the most careful setting of both parts of the abutment is necessary in order to reduce the error to a negligible amount. The exact amount of the actual uneliminated error is not known, but it is certainly less than four ten-millionths of an inch, and is probably of the order of one ten millionth.

Very careful control of temperature is also necessary during ruling, which, in the case of a big grating (say 6″ in length) takes about a week. The whole engine for this purpose is enclosed in a thickly lagged case provided with a thermostatic control which maintains the interior at a temperature which is constant within 0°.01 C.

Suppose now we have a train of waves from the same source infringing normally on a plane grating ruled in this way.

Let Figure 5 represent an enlarged section of the grating, taken perpendicular to the rulings. Then from corresponding points on each groove new waves will be propagated

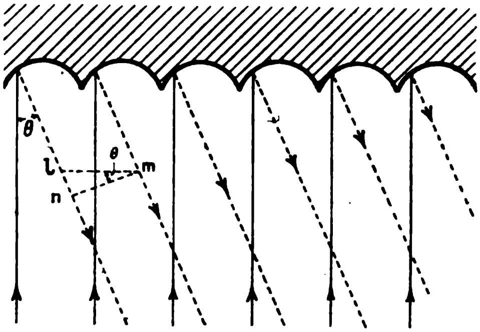

Fig. 5.

which are in phase when they leave the grating. If we consider the waves propagated in any particular direction (making an angle θ with the incident light), there will be a difference of phase, between each successive pair of waves, represented by ln, or p cosec θ, where p is the grating space. If p cosec θ is an exact multiple of one wave-length, then all the waves will be in phase and there will be brilliant illumination in the direction θ. In any other direction each successive wave will differ slightly in phase from its neighbour, and in the aggregate these small phase differences will add up so that there is little or no illumination. Thus, if we know the total length, L, of the grating and the number, n, of the lines upon it, and measure the angle θ to the position of bright illumination by means of a spectrograph, we have a direct equation

$$\lambda = p \operatorname{cosec} \theta$$

$$\text{or} \qquad = \frac{L}{n-1} \operatorname{cosec} \theta$$

connecting the wave length λ with the linear measure L.

The suggestion of a light-wave standard, therefore, was not new, but the direct method based on the use of a diffraction grating does not yield the desired degree of accuracy. Michelson adopted an interference method making use of intermediary optical standards of the type shown in Fig. 6. Each of these

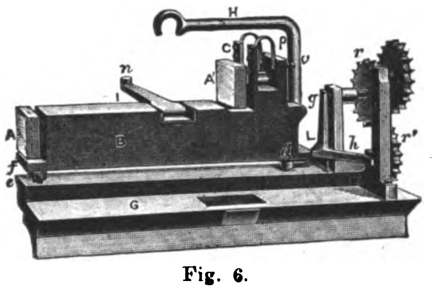

Fig. 6.

standards consists essentially of a block of metal carrying two glass plates with very carefully worked flat surfaces silvered on the front and mounted, one behind and above the level of the other, with provision for adjusting their planes absolutely parallel.

A series of nine such standards was provided, each approximately twice the length of its predecessor between the optical surfaces, the smallest being about ½ mm. in length, and the largest one decimetre. Fig. 7 gives a diagrammatic representation of the whole arrangement.

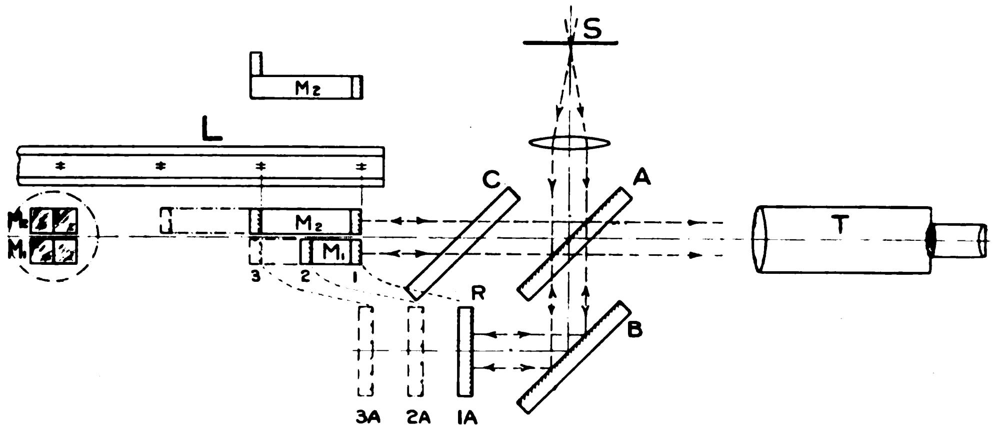

Fig. 7.

Light from a source, S, is focussed by a lens, after which it is divided by a semi-silvered surface at the back of the parallel glass plate A. Part of the beam is transmitted through this surface and reflected by the mirror B, whence it passes to the silvered surface of the reference plane R, after reflexion in which it retraces its course to A, and finally passes out to the observing telescope, T. The other part of the beam is first reflected in the semi-silvered surface of A, and then after passing through the compensator, C, is reflected at the silvered surface of M_1 or M_2, after which it passes again through the compensator, C, and also through A into the observing telescope T. The compensator, C, is cut from the same piece of glass as A, so as to be of the same quality and thickness, and is placed exactly parallel to A. The passage of the second part of the beam twice through c thus exactly compensates for the passage of the first part twice through A, and provided the distance A B R is equal to the distance A C$\left(\frac{M_1}{M_2}\right)$, the lengths of the optical paths of the two portions of the beam will be identical.

By such an arrangement interference is produced between the parts of the light which have traversed the two different paths, and an observer viewing the result through the telescope, T, will see a series of alternate light and dark bands, which may be either straight and parallel, or arranged in concentric circles, according to circumstances. If the lens focusses the light into a parallel beam, and if the reference plane R, is very slightly inclined to its theoretical direction, there will be only one ray—for example, that which infringes at the centre of the reference plane, which is of *exactly* equal optical length with the corresponding ray reflected in the mirror of the standard. On either side of this central ray there will be others which differ in phase by gradually increasing amounts from their correspondents, and for every half wave-length difference in phase there will be a change from bright illumination to darkness, or vice-versa, so that the whole field will be filled with alternate parallel light and dark bands uniformly spaced. The central band is dark, and the pitch of the spacing depends on the wave-length of the light, so that if white light is being used the bands on either side of the centre appear coloured, and very soon become indistinguishable owing to the superposition of various bands of different colours and spacing. If monochromatic light be employed the interference system will persist, even if the path lengths of the two parts of the beam are appreciably different, the maximum distance up to which it is possible to observe the fringes being governed by

the degree of homogeneity of the light waves used. One of the best sources for this purpose is the red cadmium line which was the principal wave-length used by Michelson. Neon and Krypton also give out certain very honogeneous lines, and under the best conditions it is possible to observe path differences approaching half a metre, though 20 cms. represents a practical limit for ordinary working.

In observing the fringes in monochromatic light a slightly different arrangement is adopted, the light being originally made convergent instead of parallel. Under these conditions the difference in path lengths between the two portions into which any particular period of light is broken by the semi-silvered mirror, A, depends on the distance of the virtual image of the reference plane, R, behind or in front of the mirror on the standard, and on the angle which the pencil makes with the common normal to these surfaces. As this angle increases the difference of path gradually increases, with a succession of phase changes as before, but now the fringes are disposed on concentric circles around the common normal in the line of vision.

With the aid of the fringes in white light it is easy to adjust the two standards M_1 and M_2 so that the front surfaces, say, of their lower mirrors both coincide with the virtual image of R, and consequently lie both in the same plane. By moving the reference plane slowly backwards until interference in white light is again observed in the upper plate of the shorter standard, and carefully counting all the time the successive rings which appear in monochromatic light in the lower plate, it is possible actually to count the number of wave-lengths of the particular monochromatic light employed, corresponding to the distance between the planes of the upper and lower plates of the shorter standard. It would be very tedious, and would involve too great a risk of error in counting, to do this for any considerable distance, as the number of rings passing would be so great. It is not, however, necessary to make an actual count for the longer standards. Only the shortest of them—about ½ mm. in length and containing roughly 1200 wave-lengths of red cadmium light—had to be treated in this way. When once one of the standards has been directly counted the one next larger can be determined from it as follows:—

The two front mirrors of the standards having first been brought into the same plane, and the image of the reference plane having then been brought into coincidence with the back mirror of the shorter standard, as described above, the latter is moved backwards until fringes in white light are again seen in the front mirror, *i.e.*, until this mirror again coincides with the new position of the image of the reference plane. When this is the case the shorter standard has been moved through a distance exactly equal to its own length, and the plane of its back mirror is distant twice its length behind that of the front mirror on the longer Standard. The reference plane is then moved back into coincidence with the rear mirrors in turn, and it is only necessary to count the few rings which intervene between these successive coincidences, and to add this number to twice that contained in the shorter standard in order to find that contained in the longer, and so on with each successive pair of standards until the 10 cm. one is determined.

It will be noticed that in doubling the original count of wave-lengths in the shortest standard we also double any error associated with that count, and if we were to repeat this eight times we should get an error so great as to render the work useless. But by a very beautiful artifice it is possible to maintain the same absolute accuracy of measurement for each successive standard, so long as its length is not so great that the fringes in monochromatic light become indistinct. It we use two or three different kinds of monochromatic light, of different wave-lengths, we learn from the count of the shortest standard a fairly close approximate value of their ratios. When the second standard is compared with the first we learn the whole number of wave-lengths of each kind of light contained in it, and are able to measure the outstanding fraction of a wave-length directly from the observation, to the same accuracy as before. The ratios of the wave-lengths are thus re-determined to twice the accuracy originally obtained, and the new ratios should agree with the old ones within the limit of experimental error. If they do not some mistake has been made in the count of the whole number of wave-lengths, and it is very easy to correct this by taking the excess fractions actually found, and comparing these with the results obtained by calculating from the observed excess fraction for any one wave-length what should be the excess fractions

for each of the others, taking various values for the whole number associated with the first wave-lengths. It will be found at once that there is only one value of the whole number which gives concordance between the calculated and observed results for all wave-lengths. This control is of the greatest value as a check and time-saver, and at the same time enables accuracy corresponding to a small portion of a wave-length to be maintained throughout the measurements right up to the decimetre sub-standard.

The last stage in the operation is to step up from the decimetre sub-standard to the metre length. For this purpose the decimetre standard is provided with a graduation mark carried upon a small arm, and this is brought, under a micrometer microscope, into coincidence with the graduation at one end of a special metre bar, which has been carefully compared with the international metre in a comparator in the ordinary way. By means of the fringes in white light the reference plane, R, is brought into coincidence with the back mirror on the decimetre sub-standard, which is then moved backwards until its front mirror in turn coincides with the reference plane. The latter is then moved again so as once more to coincide with the rear mirror on the sub-standard, and so on alternately until the latter has been moved through ten times its own length. The graduation mark attached to it will then be approximately coincident with the graduation at the other end of the metre bar, and the amount of the difference can be measured on the second micrometer microscope.

Another method of wave-length measurement, more simple and direct in conception than that of Michelson but perhaps more fatiguing to the observer as the fringes are difficult to see, was devised by M.M. Fabry and Perot. I do not propose to describe this method in detail, but the principle of it is as follows. Suppose we have two sub-standards each consisting of two glass plates with optically flat semi-silvered surfaces maintained parallel to each other at a definite distance apart; and suppose one such standard to be twice as long as the other.

Let the two standards be placed in line, and let a beam of light pass through them in the common direction of their length. Such a beam may be divided in a number of ways by successive reflections and transmissions at the various surfaces of the glass plates. We consider essentially two portions into which it may be broken. The first portion is reflected once in each of the semi-silvered surfaces of the longer standard, and otherwise passes straight on through the whole system. The second portion also passes straight through, except that it is reflected twice in each semi-silvered surface of the shorter standard.

It is easy to see that if the longer standard is *exactly* double that of the shorter, the two portions of the beam traverse paths of exactly equal optical length, and therefore emerge in phase, and the whole field will be uniformly illuminated. If, however, the one standard differs appreciably from twice the length of the other, there will be a difference of optical path which will depend on the angle which the rays of light make with the common normal to the surfaces, and circular fringes will appear. Parallel fringes in white light can also be obtained by the interposition of an optical wedge consisting of two glass plates close together, with a very small angle between them. Such a wedge can be calibrated for the thickness of its air film, and the position noted to which it has to be moved in order that the thickness of this film shall be equal to the difference in length between the longer standard and twice the shorter.

It is also possible, using a single short standard only, to obtain interference between the light which passes directly through it and that which is reflected once to and fro within it. The difference of phase of these two portions of the light is precisely the number of wave-lengths contained in twice the length of the standard. The fringes are circular, and located at infinity. By measuring their angular diameters, it is possible to calculate, knowing only approximately the total number of wave-lengths, the exact amount of the fractional excess. And if this be done with several different kinds of monochromatic light in turn, it will at once be found that there is one, and only one, whole number for each kind of light which can consistently be associated with the series of excess fractions so determined. Thus both the total number and also the fractional remainder of wave-lengths of each particular kind of light contained within the length of the standard can be obtained without the necessity of making an actual count. In this way, Fabry and Perot were able to step up from a relatively short standard (6.25cms.) directly determined, by multiples of 2, to one of

approximately 1 metre in length, without needing to use excessively long optical path differences, which, owing to imperfect homogeneity in the source of light, lead to confused and indistinct fringes.

The sub-standards used by Fabry and Perot are shown in Fig. 8, and were con-

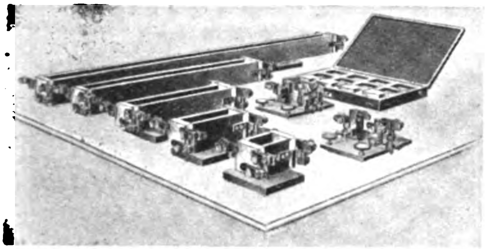

Fig. 8.

structed of "invar," an alloy of iron with 36% nickel, which has the peculiar property of being almost unaffected in length by change of temperature, and so is peculiarly advantageous for work of this kind where parts of the apparatus which it is important to keep as constant as possible, are necessarily exposed to the surrounding air.

Three small projecting studs at each end of the channel were carefully adjusted to serve as permanent supports against which the glass plates were lightly held by spring clips, in such a manner that their surfaces were exactly parallel. Invar, for reasons which I will explain later, is not suitable as a material of construction for primary standards, but is invaluable for purposes such as that here in question.

On the upper edges of the glass plates of the longest standard, quite close to the silvered surfaces, are ruled fine graduation lines, and when the optical length between the glass faces has been determined, the mechanical length between these graduations has also to be compared, by an ordinary comparator method, with that of the standard metre. To get the value of the latter in wave-lengths, it is then lastly necessary to determine the optical equivalent of the sum of the small distances between the graduation marks on the edges of the glass plates, and their silvered surfaces. This can be done quite readily by mounting the two glass plates temporarily on two special short standards, one about twice the length of the other, and determining the relationships between the mechanical and optical lengths of these.

If the value of the required small difference be denoted by A, we thus get the equations :

$$L_1 = 2L_2 + x$$

$$\text{or } \lambda(E_1 + A) = 2\lambda\ (E_2 + A) + x$$

$$\text{and } E_1 = 2E_2 + y$$

$$\text{whence } 2\lambda E_2 + \lambda y + \lambda A = 2\lambda E_2 + 2\lambda A + x$$

$$\text{or } \lambda A = \lambda y - x$$

$$A = y - x/\lambda$$

and so finally the value of the metre in wave-lengths is obtained.

The results of three independent investigations by Michelson's method made in 1892/3, were as follows :—

Michelson	1 metre =	1,553,162·7
,,	1 metre =	1,553,164·3
Benoit	1 metre =	1,553,163·6

wave-lengths of cadmium red light, and the means of all the results, for the three different cadmium rays, were :—

Red	1 metre = 1,553,163·2 λ_R
Green	1 metre = 1,966,249·7 λ_G
Blue	1 metre = 2,083,372·1 λ_B

or

$\lambda_R = 0{\cdot}64384722\mu$
$\lambda_G = 0{\cdot}50858240\mu$
$\lambda_B = 0{\cdot}47999107\mu$

the wave-lengths being measured in air at 15°C. on the "verre dur" thermometer scale at a pressure of 760 m.m. of mercury.

The result found by Fabry and Perot, about 15 years after, for red cadmium light (the most monochromatic of the series) was

1 metre = 1,553,164·13 λ_R,
or $\lambda_R = 0{\cdot}64384695\mu$

for air under standard conditions (temperature on absolute scale).

In their memoir they point out, however, that Michelson's results were subject to a small, but in the absence of records no longer determinable, correction for the hygrometric state of the air at the time of his observations. The figure

$\lambda_R = 0{\cdot}64384722\mu$

if corrected for different degrees of saturation of the air, and also for the change from the "verre dur" to the "absolute" temperature scale, becomes,

for 50%	saturation	0·64384704μ
60%	,,	0·64384700μ
70%	,,	0 64384695μ

a result which is in such remarkable accordance with that found by themselves as to be almost certainly in part due to a lucky chance.

At the same time, the figures I have quoted show that the determinations, by either method, have an accuracy closely comparable with that with which it is possible to compare two material line

standards in an ordinary comparator. And clearly, no higher accuracy than this is possible, since an ultimate comparison with such a standard, in either case, forms one essential step in the work.

We have thus at length acquired a "natural" control for our material standard of length, and a means, if necessary, of reproducing them should they become damaged or lost, which is as accurate as the present state of development of the art can employ. It remains now to enquire somewhat into the possibility of future improvement. For the demands, both of science and industry, are ever for finer measurements, and we cannot allow ourselves merely to rest on what has already been achieved. The problem of further advance resolves itself into these questions :

(*a*) Can we improve the definiteness of our material standards ?

(*b*) If we can achieve (*a*), have we then any assurance as to the sufficient secular stability of the material standards themselves, or as to the possibility of applying increasingly stringent control by means of wave-lengths or other natural standards ?

With regard to the first of these questions, it is obvious that unless the definiteness of the existing standard is higher than the accuracy of the available methods of measurement, no improvement in procedure will enable us to carry forward any increased precision into the future. The only thing we can do, if improved apparatus or methods should become available, is to prepare a new standard, more definite than the existing one, and to recognise that the measure we are passing on may carry with it a discontinuity of any amount up to the possible uncertainty of the discarded standard. The existing line standards—particularly the British Imperial Standards—of the present day exhibit this disability. The graduations on them are suited only for observation with low power microscopes, and this limits the accuracy attainable on the comparisons to something between 1 part in two million and one part in ten million. If the lines are viewed with higher powered microscopes they show irregular outlines, and accurate settings of the cross-wires become impossible. To overcome this, Tutton suggested that a new standard should be made, each end graduated with a group of five very fine lines, close together, of such proportions that the group taken as a whole would be capable of comparison under a low power microscope with the existing standard, while the centre line of each group might serve under higher powered microscopes as the defining graduation of the new and more precise standard. Fine lines of this kind are commonly made in ruling diffraction gratings, and some special experimental rulings for the purpose were actually made for Dr. Tutton by the late Mr. V. Grayson, of Melbourne, Australia, who had acquired unique skill in this class of work. It might seem at first sight that this proposal would actually have the effect of carrying forward the existing standard with a precision of which in itself it is not capable. A little reflection, however, will soon show that, while a new and more precise standard might be inaugurated in this way, its relation to the existing standard could be no more accurate than the latter already admits of.

In my opinion, the best hope of an improved material standard for the future, lies in a reversion from the line standard, which, for about the last 80 years, has held the field, to the earlier form of an end standard. The objections to the end standard formerly were that it was not found possible to finish the ends with sufficiently high accuracy to give great precision of measurement, and secondly, that the ends were liable to damage by the continual rubbing of contacts made during measurement.

Both these objections may now be dismissed. By methods recently developed at the National Physical Laboratory, which I will describe presently, it is now possible to finish the ends of long end bars with a mirror-like finish, optically flat, and parallel to each other within a few millionths of an inch. There is no difficulty then in comparing such bars by optical methods without even touching the ends at all, so that reference bars of this type could be kept just as free from damage as existing line standards, and compared even more readily with working standards of similar type, which there would be no objection to using in measuring machines in the ordinary way. An end standard of this form and perfection of finish has also the great advantage over the line standard that it lends itself readily to direct determination in terms of wave-lengths of light, without the necessity of any intermediate comparator measurement since its two end surfaces can be directly employed as part of an interference system.

It is also possible, by methods I will describe, to get very accurate determinations of sub-multiple end standards of this type, and the smaller of these can be directly compared mechanically with flat-ended crystal quartz standards of similar length.

The use of crystal quartz for length standards is a relatively new idea, and was first developed at the Bureau International des Poids et Mesures, Sèvres, at the instigation of the International Committee of Weights and Measures founded under the Metric Convention of 1875. The method of standardising these pieces was recently described in a paper by M. Perard, one of the assistants at the Bureau, and depends on an adaptation of the principle of the Michelson interferometer. (Fig. 9.) The

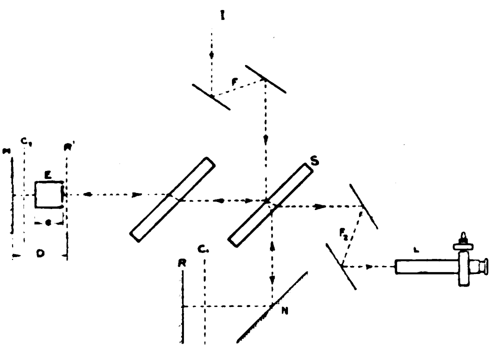

Fig. 9.

transparent quartz end standard is placed in front of a mirror, and fringes are observed in turn between the image R^1 of the reference plane R and the mirror M, first without and then with the quartz intervening. Screens C_1 and C_2 are then placed before the mirror M, and the reference plane R, and direct interference is observed between the parts of the incident light which are reflected externally at the front surface of the quartz and internally at its rear surface.

If D be the distance between M and R^1, e the thickness of the quartz, and n its refractive index for the particular wave-length λ employed, we then get three equations.

$$p\lambda = 2D$$
$$p'\lambda = 2(D-e) + 2ne$$
$$p''\lambda = 2ne$$

where p, p′ and p″ are the numbers of wave-lengths observed in the three cases.

From these, by elimination.

$$2e = (p + p'' - p')\lambda$$

Actually, only the fractions of wave-engths are observed, with several different wave-lengths, by measuring the angular diameters of the circular fringes, as described above.

We thus know the fractional part of $(p + p'' - p')$, and then with only an an approximate preliminary knowledge of λ and e we are at once able to identify, by a comparison of the fractional remainders for the various wave-lengths, the whole numbers of wave-lengths, and so complete the exact determination.

Incidentally, we have also

$$(p' + p'' - p)\lambda = (4n - 2)e$$

From which equation it is possible, so soon as the ratio of e to λ has been determined as above, to calculate also to an accuracy not previously realised by any other method, the value of the refractive index, n, of the quartz for each wave-length used.

The great prospective value of natural crystal quartz end standards as a future control for measures of lengths lies in three properties :—

(1) The fact that the material is practically immune from any attack by atmospheric or other conditions, and that the end surfaces can be brought to the highest perfection of optical polish without risk of subsequent deterioration.

(2) The ease with which their lengths can be verified, as just described, by direct comparison with wave-lengths of light in a manner which involves no actual contact with the surfaces.

(3) The fact that the material is not only extremely ancient, but that the regular arrangement of its molecules in crystalline array seems in itself to preclude any probability of secular change due to alterations in its internal structure.

The main possible objection to its use as an ultimate reference would appear to lie in the fact that it is not possible to obtain specimens much longer than one decimetre in length, so that, for the same absolute accuracy in measurement the proportionate accuracy obtained is only one-tenth what would be obtained with a metre standard. Against this, however, must be recorded the fact that in the experiments referred to, with quartz standards up to 30m.m. in length, M. Perard obtained results of astonishing accuracy. In no case did any observation differ from the final mean result by more than $0{\cdot}02\mu$, and the mean was probably correct to within $0{\cdot}005\mu$ (one five-millionth of an inch)—a result at least as good, and probably rather better, in proportionate

accuracy than is attainable in comparing first-class metric line standards with the best apparatus available at the present time.

The highest accuracy of proportionate measurement yet attained is that of the Fabry-Perot method, and this is limited mainly by the limitation of the accuracy attainable in the actual comparator work involved in the transference from the 1-metre optical standard to the existing fundamental standard, which is of the "line" type. I want to show you now how I think a further advance is possible.

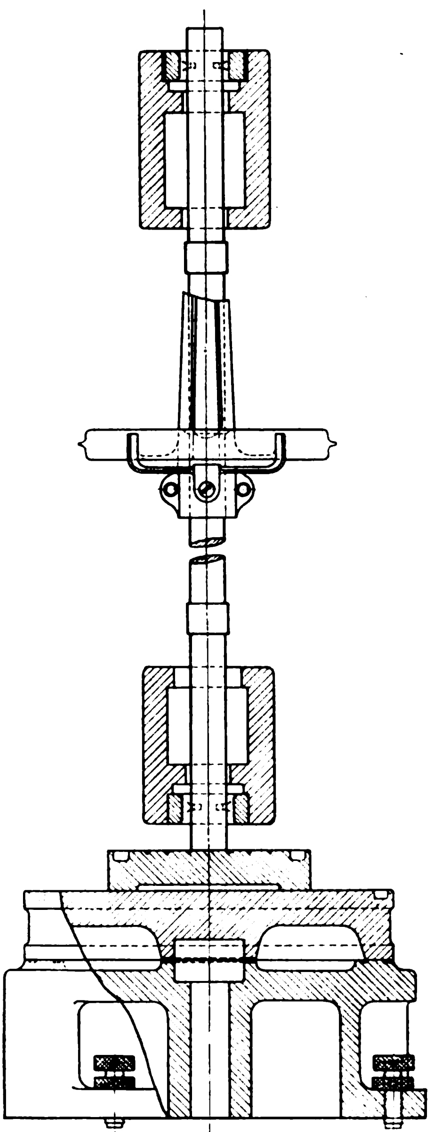

Fig. 10.

I mentioned earlier in the evening, that a great improvement had recently been effected at the National Physical Laboratory in the perfection of mechanical finish of ordinary metal end standards. I have here a bar finished by the new method, which is due to Mr. A. J. C. Brookes, who was, until recently, a member of the staff of the Metrology Department, but who has now left with a view to developing the commercial possibilities of this and certain other kindred inventions for which he has been granted Letters Patent.

The principle of the method is extremely simple. The bar to be finished is of circular section, and is held with its axis vertical between two brackets, rigidly clamped to a base which is bolted to a solid wall (Fig. 10). A very sensitive level is attached to the bar at some point by means of the special fitting shown in the figure, and the brackets are provided with adjustments by means of which the bar, at either its upper or lower end, can be moved slightly, in any horizontal direction, until, when it is rotated into any position about its vertical axis, the position of the bubble in the level remains unchanged. The axis of the bar is then exactly vertical. Beneath it is a larger bracket also bolted to the wall, on which there is a flat surface plate, which can be adjusted by means of a sensitive level until it is exactly horizontal. On the underside of the surface plate there is a flat annulus, exactly parallel to the upper surface, upon which it rests, so that when adjusted, the surface plate can be rotated in its own plane, without sensible error. A small lapping block, with upper and under surfaces accurately flat and parallel, is moved to and fro upon the surface plate, and the end of the bar rests on the upper surface of this block, which is charged with abrasive. The bar and the surface plate are both rotated from time to time by hand, and the lapping block is given a continuous circular motion also by hand. In the result, the end of the bar is eventually brought absolutely flat, and square to its axis. The bar is then turned upside down, and re-adjusted, and the other end similarly lapped in turn. The final result is that each end of the bar is finished to a flat surface of optical perfection; and the two end-surfaces, being both perpendicular to the axis of the bar, are also parallel to each other to a very high order of accuracy. The ends of the bar exhibited on the table are both

flat, and parallel over their entire surfaces, within a few millionths of an inch.

Accuracy of this kind, in the finish of an end standard, opens up possibilities hitherto out of reach. For instance, by a very simple modification of the Fabry-Perot method it is possible to determine the length of such a standard directly in terms of the wave-lengths of light, without the intervention of any comparator measurement, and without touching the ends of the bar in any way. To do this, the distance between the inner surfaces of two glass plates, rigidly fixed on the bed plate of the apparatus, is first determined precisely as in Fabry and Perot's experiment, by comparison with a succession of shorter optical standards each approximately half the length of the preceding one. These sub-standards may very readily be made by "wringing" the glass plates on to the ends of tubular invar gauges, made with accurately parallel ends, by the same method as the standard bar itself. The standard bar, on a pivoted and counter-balanced support, is then placed between the plates, without disturbing the distance between them in any way, and by means of a simple interference measurement, the small distances between the end-faces of the standard and the semi-silvered surfaces of the plates are determined. The difference gives us the length of the bar in wave-lengths of light. It is also possible, by the interference method, to compare the lengths of two such bars without touching the surfaces of either. Neither of these methods, however, has yet been worked out in all experimental details, and I will not devote further time to their description.

As to the accuracy attainable in both processes, it should be possible to work to about 1/25th of a fringe, which corresponds to 1/50th of a wave-length. And the mean wave-length of ordinary visible light (green) is about 1/2000 mm., so that the accuracy should approach one part in 100 million on a 1-metre length—an advance, certainly, of ten times on the existing standards and methods.

It has to be recognised, of course, that certain conditions must be fulfilled before an enhanced accuracy such as this can usefully be employed.

In the first place, the length of the standard will vary with temperature, and if made of any ordinary material, to fix its length within 1 part in 10^8 would involve, knowing its temperature to $0^\circ{\cdot}001$C.

This represents about the limit of accuracy of which present-day thermometry is capable, and it would certainly not be possible, in the ordinary way, to determine the temperature of the bar to this accuracy, with the aid of any type of thermometer which did not form an actual part of the bar itself. Experiments are in progress at the National Physical Laboratory, having for their object the production of an end standard of the type in question, but incorporating in its construction a platinum resistance thermometer, forming a permanent feature of the standard, and capable of recording the actual temperature within its substance to $0^\circ{\cdot}001$C.

Secondly, unless we have some means of satisfying ourselves as to the secular stability of the standard, the increased accuracy is of little real value. Of course, if we find always the same value for the standard in terms of the wave-length of a particular kind of light, this is prima facie evidence that neither the standard nor the light, has changed. This evidence is not, however, conclusive, though it would be greatly strengthened if a number of standards of different materials all gave the same result.

In the present state of knowledge, however, we have no guarantee that we can actually reproduce from time to time, wave-lengths of light from nominally identical sources, and under nominally identical conditions, which do, in fact, agree within the very high degree of accuracy here in question. It should not, however, be a very difficult problem to ascertain the conditions of reproducibility of wave-lengths by comparing the results of tests on the same standard at intervals of time so short that any secular change would be negligible, and varying the conditions of production of the light as much as possible. This is an investigation which appears now to be urgently needed, and, given a favourable outcome, it would apparently be best, for the future, to re-define both the yard and the metre as containing so many wave-lengths of a certain kind of light under certain specified conditions, and to use standards of the end-bar type, merely as the most conveniently controlled material representations of these definitions. The material standards would no longer be fundamental, but their errors would be known, with a higher precision than the

lengths of the present day standards are known, in terms of the new definitions.

Before finally leaving the subject of natural controls on standards of length, I should like to mention a new control which the production of these very perfect end-standards, coupled with certain other recent scientific discoveries, seems to make possible. As you all know, the accepted standard of time is a purely natural one, based solely on the speed of rotation of the earth upon its axis. The rate of a standard clock is ascertained by means of astronomical observations of the transits of the fixed stars. The speed of the earth's rotation is, of course, not absolutely constant, but is affected by changes in the distribution of its material due to internal cooling, and by the frictional effect of the tides upon its surface. The actual amount of the variation is, however, so small that astronomical methods, based on observations of planetary eclipses, have so far failed to determine its actual amount. The length of the mean sidereal day is, however, supposed to be increasing at a rate not exceeding one hundredth of a second per century. That is to say, the length of a day is constant to within about one part in ten millions per century.

It has been discovered that the recently invented electrical triode valve, which is to-day in almost universal use for transmitting and amplifying the electro-magnetic oscillations employed in wireless telegraphy and telephony, can be used to maintain a tuning fork in sustained oscillation, without the intervention of any mechanical contacts, in a manner which therefore exerts only the minimum reaction on the free period of vibration of the fork. The ordinary tuning fork, regarded as a permanent standard of time, is, of course, far from ideal, both in the form and material of its construction. But it occurred to me that a bar, such as one of the end-standards I have shown you, with its terminal surfaces absolutely flat and perpendicular to its axis, if it could be similarly maintained in continuous longitudinal vibration, would be absolutely ideal, both from the simplicity of its form and from the perfection with which the elastic waves would be reflected in its mirror-like ends, to serve this purpose.

I accordingly had a special bar made, similar in every way to one of these end-standards, but provided with a small projecting rim at the centre of its length by means of which it could be gripped and supported at a nodal point, and in a vertical position in order to avoid any flexure of its axis. And after some preliminary experiments it has been found perfectly possible to maintain such a bar in continued longitudinal vibration for hours at a time, using either magnetic attraction, or the variation of electrical capacity, between the vibrating end of the bar and a flat plate fixed parallel and very close to it, as the source for driving. The latter method, though slightly more difficult, has the advantage in several respects. The minute variations in the distance itself (only about 0·001 inch) between the end of the bar and the plate, cause a variation in the capacity of the condenser, and consequently, the charge being constant, a variation in the electrical potential, which is transmitted to the grid of a valve. This allows more or less current to pass through the anode circuit, the variations in which, being transmitted to the condenser at the other end of the bar, cause variations in the electro-static attraction between the plate and the bar at that end, and so serve to keep the vibration going. The bar is one metre long and vibrates about 2,500 times a second. It will continue to sound an audible note for some 20 seconds—or 50,000 vibrations—if gently tapped and allowed to die away naturally in air, so that it is clear that only an extremely small amount of energy is required at each vibration in order to maintain it at the same amplitude continuously. And from this it follows that, given suitable conditions, its natural free period will be sensibly unaffected by the forces required to maintain the oscillation.

It happens that ordinary materials, such as steel or nickel, are very much affected as regards their elastic constants, and, consequently, as regards their period of free vibration, by changes in temperature—the change in period being of the order of one part in 10,000 per 1°C. But Dr. Ch. Ed. Guillaume, the Director of the Bureau International, well-known as the discoverer of invar, has also discovered another nickel iron alloy, to which he has given the name "elinvar," since it has the very remarkable property that the effect of its thermal coefficient of elasticity is almost exactly balanced by that of its thermal coefficient of volume, so that its period of free vibration is only affected to the order of one part in a million by a change of 1°C. in temperature. This alloy has already found an important

application in the construction of hair springs for high-grade watches, and a bar of it was obtained specially for the purpose of the experiment I am now describing.

The preliminary bar is shown, one half exposed, and one half hidden by the tubular support of the driving plate, in Fig. 11.

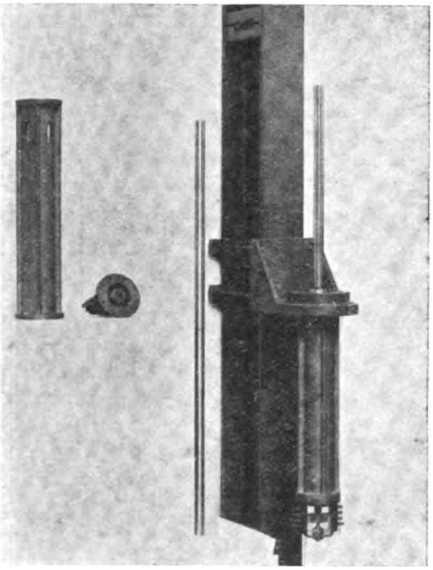

Fig. 11

When in action, a similar tube is fitted over the upper end to carry the plate which receives the vibrations. When finally completed, the whole will be enclosed in an air-tight chamber, thermostatically controlled, and it is anticipated that there will be no difficulty in keeping the temperature inside this enclosure constant to 0°·01C., or even 0°·001C. Taking the more modest figure, the constancy of period should then be one part in 1000 million. It has been found possible, in another connection, to make actual counts of electrical oscillations, such as those which here serve to maintain the vibrations of the bar, by means of an apparatus known as a phonic wheel. No actual count has yet been made of the vibrations of the bar, but a design has been prepared for a special phonic wheel suitable for the very delicate conditions required by the experiment, and the construction of this is now being undertaken. Supposing that the counting is successfully effected, we shall then be able, from time to time, to compare the number of vibrations made by the bar in a day with star transits, and to determine whether any relative change is taking place between the length of the day and the period of vibration of the bar. If no such change is observable, it may be concluded that the physical properties of the bar, including its length, have remained as constant as the day, *i.e.*, within one part in ten million per century. The accuracy which may be anticipated is higher than that at present attained by the astronomical observations, so that, could we be quite sure that the bar remained perfectly constant in its properties, we could hope to reverse the process, and to measure by its means the variations in the earth's rotation.

Dr. Guillaume, in reply to an enquiry of mine as to the constancy of elinvar, wrote: "sa stabilité seculaire est parfaite." He would, however, I am sure, have qualified this exceedingly bold statement had he known that I was thinking of it as a sort of super-control on other standards of length, and, as a matter of fact, the secular constancy of the bar, to the order of accuracy desired, is the first thing which needs to be established, and this must necessarily be a process lasting many years.

It is hardly possible to predict whether the science of metrology, or that of astronomy, will have made the greater progress a hundred years hence, but in either event, the material link thus provided between the standards of length and time can hardly fail to be of the greatest value in one sense or the other.

NOTES ON BOOKS.

Economics for Commercial Students. By Albert Crew. Sixth Edition. London; Jordan & Sons, Limited. 1923. 5*s*. net.

In its new and enlarged edition, Mr. Crew's well-known text book embodies between 400 and 500 closely printed octavo pages, and the moderate price (5*s*.) should secure it a place in many libraries, whether public or private.

Mr. Crew's work being intended specially for readers having the commercial habit, the author has evidently endeavoured to meet the needs of those who wish to read quickly, and without such hindrance as may rise from an unduly minute or too academic differentiation of terms and subject matter. Thus the wording is much more concise and less formally dialectic than if written exclusively for those who strive to balance and adjust every word or every grammatical form, and who think in the slow and laboured styles of Aristotle, Kant, Sismondi, Bentham and most of the early economists.

We may congratulate Mr. Crew on the general scheme or construction of the book, and on the skill with which he arranges his specially difficult subject; the concise boldly-headed paragraphs, the cross references, and the good index helping materially.

By such expedients as we have mentioned every aspect of political economy and economic history is embodied in a minimum of words; moreover, the avoidance of any pronouns which may disturb the sequence of the reader's ideas or occasion uncertainty, is a very real merit which conduces to easy reading, and Mr. Crew's handbook may do much towards removing the undeserved reproach as to economics being "the dismal science."

When a matter is highly controversial, as, for example, state socialism as against capitalistic organisation, the arguments for and against are stated in short numbered paragraphs (pp. 300-302), so that any argument can be readily referred to by number. Similarly, we have (pp. 225-228) a tabulation of 23 arguments as regards protection —for and against.

The chapter on "Index Numbers" (pp. 173-180) deals concisely with an aspect of things which has come to the front as a result of the war, and reference is given to Bowley's Elements of Statistics for further particulars.

FOREIGN EXCHANGES: REPARATIONS.

To illustrate still further the up-to-date character of the treatise, we may refer to Section VI. International Trade, and as Mr. Crew is a recognised authority on mercantile law, this section has notable value. The nature of Foreign Exchange and a study of the consequences of a depreciated currency, are followed by a lucid summary as to "invisible exports" and their influences: an example of invisible exports being "services rendered by our ships, our agents, and our insurance companies to subjects of foreign states." (p. 208.)

A note on the question of German reparations (p. 214) suggests that whatever we may get from Germany, must, under present circumstances, involve some degree of countervailing disadvantage. Mr. Crew considers the various difficulties, and makes reference to the suggestion that from the point of view of British trade only, it would be better if reparations were remitted. He, however, says:—"—the problem is so complex that for the moment it seems unsolvable."

GENERAL NOTES.

PHYSICAL AND CHEMICAL SURVEY OF THE NATIONAL COAL RESOURCES.—One of the main functions of the Fuel Research Board is a survey and classification of the coal seams in the various mining districts by means of chemical and physical tests in the laboratory, supplemented where desirable by large scale tests at H.M. Fuel Research Station, East Greenwich, or elsewhere. The Board consider that the best way to carry out this work is by means of local committees, the personnel of which would include colliery owners, managers, representatives of the Fuel Research Board and of the Geological Survey of Great Britain, as well as of outside scientific interests. Each committee would be charged with the duty of superintending the work of the survey in a coal mining area; and in this way the survey would become from the commencement of practical value, since local knowledge and experience would be made available, and the selection of seams would be decided by those most likely to estimate correctly the relative importance of the problems to be solved. The seams selected would undergo physical and chemical examination by the local experts, after which a final selection would be made of those likely to justify experiments on a practical scale to test their suitability for particular uses or methods of treatment. The first of these committees has now been actively at work in the Lancashire and Cheshire area for nearly eighteen months, and the Board have recently appointed a committee to deal with the survey in the South Yorkshire area. The composition of the committee is as follows:—Mr. J. Brass, Mr. Robert Clive (Hon. Secretary), Mr. H. Danby (representing the South Yorkshire Coal Trade Association); Lieut.-Col. H. Rhodes (representing the Midland Institute of Mining, Civil and Mechanical Engineers); Prof. R. V. Wheeler, Mr. C. H. Lander (Director of Fuel Research, Chairman *pro tem*) (representing the Fuel Research Board); Dr. Walcot Gibson (representing the Geological Survey of Great Britain).

MERCURY MINE IN KWEI-CHOW.—The mercury mine of Dong-shun-hsein Kwei-chow has been in operation many years. According to the natives, their ancestors were engaged in mercury mining in the Ming Dynasty, 1368-1644. The veins are found in the limestone strata and in isolated patches or pockets. There are two kinds of mercury. One is red and transparent, and the other dark-red and opaque. The latter contains a small amount of antimony, but neither contains pyrite. The methods used in opening the mine and in smelting the mineral are very crude.

MOTOR CARS IN CHINA.—In 1922, according to the Tientsin trade report, 248 motor cars were imported. Of the total, 115 came from the United States, 63 from Germany, 21 from Italy, 6 from Great Britain, 18 from France and 15 from various other countries.

IRON AND STEEL INSTITUTE.—The autumn meeting of the above Institute was held in Milan on September 17th and 18th. Among the papers submitted was one on "The Iron and Steel Industry of Italy," and another on "The Iron Ore Mines of Nurra (Sardinia)." At the conclusion of the meeting visits were paid to Florence, Rome, Plombino, Leghorn and Turin.

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

PRECISE LENGTH MEASUREMENTS.

By J. E. Sears, Junr., C.B.E., M.A., M.I.Mech.E., A.M.Inst.C.E.

Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards.

Lecture II.—*Delivered March 12th,* 1923.

ON THE DETERMINATION OF DERIVED STANDARDS.

At the end of my first lecture I showed you a bar end-standard with its two terminal faces finished with extreme accuracy flat and parallel to each other. And I gave you reasons for supposing that a bar of this type might prove superior, as a material standard, to the graduated line type at present adopted for this purpose. At the same time I indicated a hope that it might prove possible in future to replace material standards, for purposes of fundamental definition, by reference to the wave-length of light under properly prescribed conditions.

But whatever may be our fundamental definition, and whichever type of standard we may choose as the most satisfactory material representation of our unit, it is certain that both line measures and end measures will be needed for every day use in science and industry. The operation of conversion from the end to the line type, or vice-versa, is, therefore, one of prime importance, and I propose next to describe one or two methods by which this operation —one of the most difficult in the whole art of metrology—can be performed.

Before doing so, however, it will be convenient to refer briefly to another subject, which will facilitate the explanations to be given. I have on the table a set of end gauges, varying in length from one-tenth of an inch to four inches, made by the Swedish firm of Johansson, by whom this type of gauge was first introduced. They are finished with extreme perfection, as regards flatness and parallelism of their measuring faces, and I want first to demonstrate one most remarkable phenomenon resulting from this perfection of surface. Taking two of these gauges and cleaning their end surfaces very carefully, I gently slide one over the other, using a gentle pressure only, and you will see that the gauges then adhere to each other, so strongly that by a direct pull, perpendicular to the common interface, it is hardly possible to separate them again. Experiments have shown that with good "wringing," as it is termed, the tensile strength across the interface may amount to as much as 65 lbs. per sq. inch. The gauges are not magnetic, and it appears that the effect is due to surface tension of a very thin film of grease or moisture between them. For if very carefully dried it is found impossible to make them adhere, though, with the very slightest trace of lubricant, or even the moisture due to handling, they will wring together readily. If too much lubricant is used, of course, they will simply slide over each other.

The mechanism of the adherence is indicated by the appearance of the surfaces under a microscope immediately after forcible separation in the direction of the common normal. A large number of very small circular spots are seen, which represent small patches of the lubricant. When the two surfaces are in the course of separation it may be supposed that the lubricant is separated into a large number of minute isolated patches, each of which is surrounded by a surface tension film, and that the aggregate of all these small surface tensions makes up the total force binding the two surfaces together. When separation is effected, half the lubricant is distributed on each surface, in a series of small spots. If we know the angle of repose of the lubricant used, and measure the mean diameters of the spots under the microscope, we can calculate their volumes, and so deduce the thickness which the film would have when the

whole of the lubricant was distributed uniformly between the two surfaces. The results of this investigation are rough, but in reasonable accord with the facts observed.

The thickness of the wringing film has also been measured directly, by the method of optical interference, by M. Pérard, of the Bureau International, by first determining the individual lengths of a number of gauges in terms of the wave length of light, and then that of their sum, when wrung together. He finds the rather surprising result that, with the various lubricants he investigated, the thickness of the film which gives the most satisfactory wringing is practically independent of the lubricant used, and equal to about 3 millionths of an inch. Subsequent comparative investigations at the N.P.L., however, have shown that while petrol and paraffin give almost identical thickness of film, vaseline oil gives a film very slightly thicker, while a recent publication of the Bureau of Standards, Washington, states that with pure alcohol a film only 1 millionth of an inch thick is obtained.

The set of gauges introduced by Johansson (Fig. 12) is a special one, comprising 81 pieces, including the following series :—

4″, 3″, 2″, 1″ . . . . (4 pieces)
0″.95, 0″.90, 0″.85. . 0″.15, 0″.10, 0″.05 . . . .(19 ,,)
0″.101, 0″.102 . . . . 0″.149 . . (49 ,,)
0″.1001, 0″.1002 . . . . . . 0″.1009 . . (9 ,,)

The four largest pieces are each guaranteed accurate within 1 part in a hundred thousand, and the smaller pieces all to within one hundred thousandth of an inch. By wringing together a suitable selection of gauges chosen from a set of pieces arranged in this fashion, it is possible to build up a combination gauge of any desired size, correct to the nearest ten-thousandth part of an inch. For example, if we want a temporary gauge 1.8576 inches long we may select the following :—

1.0
0.65
0.107
0.1006
———
1.8576
———

Each piece here is correct within a hundred thousandth of an inch, and the three wringing films together amount to no more than another hundred thousandth, so that the error of the combination does not exceed four hundred thousandths, and is probably less than this. The uses of such combinations in every-day practical measurement are innumerable, and I shall have occasion next week to show you a few typical examples.

It may be of interest, before passing on from this matter, to describe one method by which it is possible to produce gauges of this very high order of accuracy. The process employed by Johansson is a secret

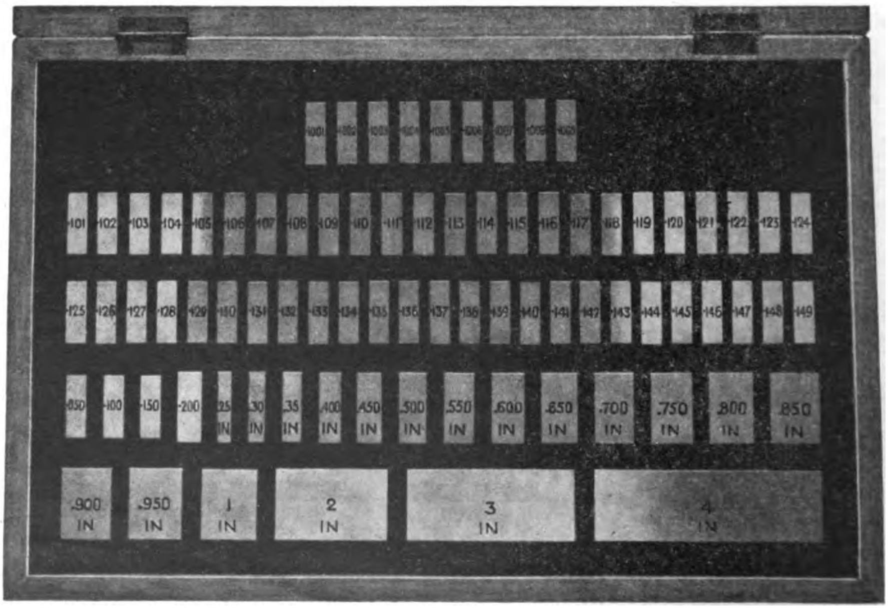

FIG. 12.

one, which has never been disclosed. There was a time during the war when it appeared likely that supplies of these gauges from Sweden might be cut off, and a process was then developed at the N.P.L. for making them, by a method devised partly by Mr. Brookes, and partly by myself, which has since been patented and is now being worked commercially under Mr. Brookes' supervision by Messrs. Pitters Gauge and Tool Co., Ltd., of Woolwich. Other similar gauges are also being made in the United States, by an entirely different method, by the Pratt and Whitney Company, and sold under the name of "Hoke" gauges.

The process which we evolved is an extremely simple one, requiring little special skill to produce highly accurate results. The gauges to be finished are first lapped flat on one side, and are then placed, eight at a time, on eight facets raised upon a chuck such as that illustrated in Fig. 13, to which

Fig. 13.

they may be held either magnetically or by simple wringing action. The facets on the chuck are first made accurately flat and coplanar by rubbing it by hand upon the surface of a flat lapping plate charged with abrasive. The lapping plates themselves are made in sets of three, and are trued up periodically by rubbing together in pairs, on the principle introduced by Sir Joseph Whitworth for truing up surface plates. When the eight gauges are in place upon the chuck their exposed surfaces are lapped by hand upon the plate until they also are all flat and coplanar. We know then that the surfaces of the gauges in contact with the chuck all lie in one plane, and their exposed surfaces in a second plane, which, however, will probably not be exactly parallel to the first.

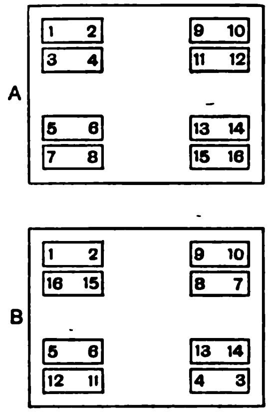

Fig. 14.

The next step is to interchange the positions of some of the gauges as indicated in Fig. 14. We may take the figures shown on the corners of the gauges as indicating, in a very general way, the differences in thickness of the corresponding parts of the gauges before the interchange. After the interchange it will be noticed that the sums of the figures at either end of any adjacent pair of gauges is the same, thus indicating that the mean thickness of each pair is identical. As a matter of fact this identity is mathematically exact, though the simple description just given does not constitute a formal proof.

The lapping is then repeated until the exposed surfaces are again reduced to lie in one plane. If the gauges are all equally

hard, and the lapping plate cuts uniformly, it follows that when this condition is arrived at, the plane of the exposed surfaces will be exactly parallel to that of the chuck facets, so that all the eight gauge pieces must now be exactly equal in thickness, and have flat parallel surfaces.

The lapping has, of course, to be continued until the correct thickness is arrived at, and the interchange must be periodically repeated during this process, in order that the parallelism, once attained, shall not be lost again by unequal lapping. It is found that the first lapping after interchange gives practically perfect parallelism.

The fact that eight gauges are automatically produced simultaneously of identical size very greatly facilitates the attainment of accuracy in size. For the eight gauges can all be wrung together, and the combination compared in a measuring machine—such, for example, as the tilting level comparator which I shall describe a little later on—with a known standard eight times as long. It is easy then to see how much further lapping is still required to reach the final size, and when this has been done any outstanding error of measurement is divided by 8 on the length of any one gauge.

FIG. 15.

There is an even simpler method of making the necessary test for size, which is indicated in Fig. 15. If the combination and the standard to be compared are wrung down side by side on a small surface plate, and a straight edge is carefully drawn across their upper surfaces it will be found that a slight mark will show on the higher of the two surfaces, while the lower will not be marked. A difference of only a hundred thousandth part of an inch can be detected in this way, and this, when divided among the eight gauges, is entirely negligible for all ordinary purposes.

I shall have occasion to refer in more detail to Johansson gauges and their uses a little later on, but the question of wringing surfaces is one that arises immediately, in connection with the conversion from line to end standards.

The most direct way of carrying out this conversion is by means of the machine illustrated in Fig. 16. The machine consists of a bed, at the right hand end of which is a headstock with a measuring face controlled by a micrometer screw, which is read by the divided wheel. The small microscope on the right serves to indicate when contact has been made on the object being measured. The carriage on the left carries the other measuring face, and beyond it a graduated scale whose divisions are arranged to lie in the measuring axis of the machine. This is a most important feature, and one to which it is necessary to give very careful attention in many cases of design for purposes of accuracy in measurement. If, as is the case in a number of instruments put on the market, an attempt is made to compare measures lying in parallel straight lines, but not in the same continuous line, considerable errors may be introduced into the results owing to practically unavoidable errors in workmanship—mainly in the straightness of the guides on which the parts have to move. But where the two measures

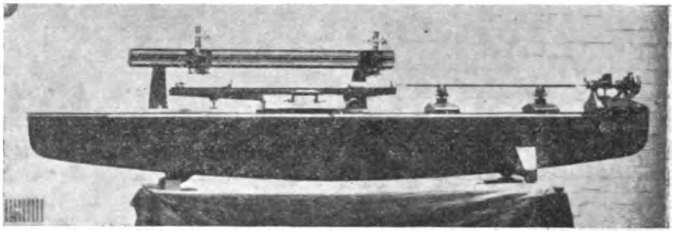

FIG. 16.

under comparison lie in the prolongation of the same straight line, only cosine errors can be introduced from this cause, and these, in general, are negligible.

The divisions of the scale are read by the micrometer microscope at the left of the machine, and the length of a gauge may be compared with that of the corresponding interval on the scale by taking readings on the divided wheel and on the micrometer microscope, first, with the two measuring faces in direct contact, and secondly, with the gauge interposed between them. The machine shown in the figure was specially made for the National Physical Laboratory and has a capacity of 1 yard or metre, and is arranged so that any standard line bar, which it may be desired to compare with an end bar of corresponding length, may readily be mounted on the carriage for the purpose.

The actual operation of comparing an end standard with a line standard by this method is not, however, quite so simple as I have described. For if the two measuring faces of the machine are not absolutely parallel, they will not come into perfect contact when brought together, but will meet somewhere round their periphery, leaving a small space at the centre, which is the line of measurement. If also the ends of the bar are not perfectly parallel both to each other, and also to the faces of the machine, the condition will again be different when the bar is inserted, and will depend on the position of the bar. To get accurate results by this method, therefore, either the measuring faces of the machine must be slightly convex (for flat ended bars), or the ends of the bar itself must be slightly rounded. In the former case, unless the centres of curvature of the measuring faces are exactly on the axis, their highest points will not meet in contact, and they will approach each other too closely, when the bar is not present, while in the latter case, as already stated, they may not approach near enough, while in both cases, when the bar is inserted this source of error does not arise. In either case, therefore, it becomes necessary to make the preliminary experiment, not with the measuring faces in direct contact, but with an auxiliary gauge (flat ended or spherical as the case may be) interposed between them. The length of this auxiliary piece has then to be determined by some means in terms of the longer bar which it is desired to compare with the line standard, before the latter operation can be completed. And lastly, since point contacts are introduced, allowance has to be made for the elastic compressions which may occur. The measurements are necessarily conducted in air, and the two standards are at some considerable distance from each other, so that the difficulty of either controlling or measuring their temperatures accurately is very great. It is practically impossible, moreover, with a micrometer screw such as is embodied in this machine, to obtain an accuracy of reading better than one hundred-thousandth of an inch. And having regard to all the difficulties mentioned the method, though initially it appears simple and direct, cannot be regarded as a good one where the highest precision is desired.

Another method which has been employed consists in viewing simultaneously the direct and reflected images of some small object—*e.g.*, the point of a needle—placed close to the end of the bar, under the microscope of a comparator, and setting the cross wires of the microscope symmetrically between these two images to get a reading corresponding to the position of the reflecting end surface. The same being done at each end of the bar it may then be directly compared, by the ordinary comparator method, with a line standard. The objections to this method are, firstly, that it is difficult to get the direct and reflected images equally sharp in definition, and equally illuminated, without which errors in setting for symmetry are likely to occur, and, secondly, that the optical conditions, using one half only of the objective of the microscope (the other half being obscured by the presence of the bar), are not couducive to accurate results.

Another comparator method, but one really suitable only for use with bars having convex ends, is as follows :—Three or more approximately equal bars are required, each provided with a graduation effectively in its neutral axis and halfway along its length. Two of these bars are then butted end to end on one girder of the comparator, and the distance between their central graduation marks compared with the corresponding interval on a known line standard.

If the half-lengths of the bars are a_1, a_2, b_1, b_2, c_1, c_2, then the result of all the possible arrangements in which the comparison can be made is to give us a series of values for—

$$\begin{array}{lll} a_1 + b_1 & b_1 + c_1 & c_1 + a_1 \\ a_1 + b_2 & b_1 + c_2 & c_1 + a_2 \\ a_2 + b_2 & b_2 + c_2 & c_2 + a_2 \\ a_2 + b_1 & b_2 + c_1 & c_2 + a_1 \end{array}$$

altogether twelve equations for the six unknown quantities which are thus determined with a sufficient number of redundant observations to give a check on the accuracy of the result. Adding the final computed values for the two halves of each bar we thus get the lengths of the three bars, each in terms of the line standard, and the accuracy of these lengths is then susceptible of a further check by comparing the bars, each with each, in an end-measuring machine.

But the best method so far devised is, in my opinion, one due to Mr. H. L. P. Jolly, formerly an assistant in the Metrology Department of the National Physical Laboratory, and now technical advisor to the Ordnance Survey, Southampton. The principle of this method is illustrated in Fig. 17 and depends on the possibility of

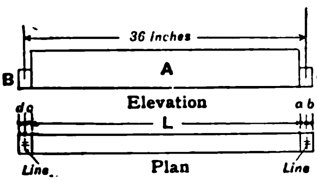

Fig. 17.

wringing two well finished flat surfaces together in the manner I illustrated just now, and on the accuracy of parallelism to which it is now possible to work the end faces, either of long bars, or short end-blocks. For it a special auxiliary bar is made, slightly shorter than the bar it is desired to compare with the line standard. For a 36″ bar the auxiliary bar may be, for example, 35½″ long; its exact length is immaterial. In addition two small blocks are prepared, each ½″ long, with opposite faces accurately flat and parallel, and with one third face also carefully polished flat and perpendicular to these. On the third face graduation marks are ruled as indicated in the figure, and the blocks are then "wrung" on to the end of the auxiliary bar in the manner shown, so that the centres of the two graduation marks are exactly in the axis of the bar. The bar in this condition is then effectively a line standard approximately 36″ in length, and may be compared directly, in the comparator, with the standard yard.

The end blocks may be wrung on in four different arrangements, and if M_1, M_2, M_3, M_4, be the measured distances between the graduation marks under these four conditions, and a, b, c, d, the half lengths of the blocks, t the thickness of the wringing film, L the length of the auxiliary bar and S the length of the line standard, we have four observational equations in the form

$$\begin{array}{lllll} L + (b + c) + 2t & = & M_1 & = & S + x_1 \\ L + (a + c) + 2t & = & M_2 & = & S + x_2 \\ L + (a + d) + 2t & = & M_3 & = & S + x_3 \\ L + (b + d) + 2t & = & M_4 & = & S + x_4 \end{array}$$

Adding these and dividing by two we get

$$2L + \Sigma a + 4t \quad = \quad 2S + \tfrac{1}{2}\ \Sigma x_1$$

We now compare the auxiliary bar with the end bar E, in an end measuring machine, this time wringing only one of the end blocks on at a time, and arranging it centrally on the end of the bar. In this way we get two new equations:—

$$\begin{array}{lll} L + (a + b) + t & = & E + y_1 \\ L + (c + d) + t & = & E + y_2 \end{array}$$

Adding again

$$2L + \Sigma a + 2t \quad = \quad 2E + (y_1 + y_2)$$

Hence, comparing this with the previous result, we get finally

$$E + t = S + \tfrac{1}{4}(x_1 + x_2 + x_3 + x_4) - \tfrac{1}{2}(y_1 + y_2)$$

giving the value of the end-standard, E, in terms of the line standard S.

What is particularly to be noted about this method is that no actual measurement needs to be made either of the auxiliary standard or of the two end blocks. Both are eliminated entirely from the final result. And in this the method is appreciably superior to any other based on somewhat similar procedure.

It will be noticed that in the final result the length of the end bar is associated with the thickness of one wringing film, t, and this cannot be eliminated. As I have already explained, however, this thickness is only of the order of 3 millionths of an inch, and may be as small as 1 millionth. It can, if desired, be allowed for. But even if it is ignored the error in the comparison due to this, on a yard length, would be less than one part in 10 millions, which is the limit of accuracy attainable in the direct comparison of line standards, so that it is unimportant. Moreover, if the end bar is to be used as a basis for the calibration of end gauges of the Johansson type, which are ordinarily used in combinations held together by wringing, we shall see later that it is $E + t$, rather than E itself, which properly should form the basis of the work.

I must now explain briefly another very

important process—that of obtaining the values of shorter or longer measures in terms of the fundamental standard. I shall deal first with line measures.

The apparatus which is used to determine the length of any subdivision of a graduated bar, as a proportion of its total length, is known as a longitudinal comparator. The bar to be calibrated is mounted on a carriage, under two micrometer microscopes which can be fixed to a rigid bed at any points along its length. The carriage can be moved, by means of a traversing hand wheel in front, in a direction parallel to the length of the bar, any pair of graduations on which can thus be brought at will beneath the two microscopes. The operations are as follows :—

Suppose it is desired to determine the lengths of the decimetre subdivisions of a metre bar. Let the graduations be numbered 0, 1, 2, up to 10. The microscopes are first fixed with their optical axes approximately one decimetre apart, and the carriage is moved until the graduations 0 and 1 appear in the central portions of their fields of view. The cross-wires are then set to the graduations, and the readings of the micrometers are noted. The carriage is then moved along, one decimetre at a time, and the same repeated on graduations 1 and 2, 2 and 3, 3 and 4, and so on up to 9 and 10, and back again. The microscopes are then re-fixed, two decimetres apart, and the same process is gone through, commencing with graduations 0 and 2, then with 1 and 3, 2 and 4, and so on up to 8 and 10, and back. Then with the microscopes three decimetres apart, readings are taken on graduations 0 and 3, 1 and 4 etc., and so on, until finally, with the microscopes nine decimetres apart readings are taken on graduations 0 to 9 and 1 to 10. The same is then repeated with the bar reversed end for end under the microscopes and the mean readings are taken. During the whole process it is assumed only that the distance between the microscopes remains sensibly constant between consecutive observations, and that the temperature of the bar is uniform from end to end. If any gradual change of temperature with time is taking place, the order of procedure is such as to eliminate its effects as far as possible. And since we are working with only one bar, provided it is homogeneous, and has the same co-efficient of thermal expansion from end to end, it is not necessary to know its exact temperature, and it is sufficient, therefore, to work in air, in a simple wooden enclosure.

If the lengths of the successive subdivisions are denoted by 0/1, 1/2, etc., then the first series of observations gives us values a_1, a_2, a_3,..for (0/1—1/2), (1/2—2/3), (2/3—3/4), etc. The second series, subtracting those portions of the length which are common to the successive observations, gives values b_1, b_2, b_3..... for (0/1—2/3) (1/2—3/4) (2/3—4/5), etc., and so on. Hence, finally, we may form a square of differences thus, the quantity entered in each square being the mean observed difference in length between the subdivision at the head of the corresponding column, and that at the side of the corresponding row.

	0/1	1/2	2/3	3/4	4/5	5/6	6/7	7/8	8/9	9/10
0/1		$-a_1$	$-b_1$					$-g_1$	$-h_1$	$-k_1$
1/2	a_1		$-a_2$	$-b_2$					$-g_2$	$-h_2$
2/3	b_1	a_2		$-a_3$						$-g_3$
3/4	c_1	b_2	a_3							
4/5										
5/6										
6/7										
7/8										
8/9										
9/10	k_1	h_2	g_3							

Adding any column, for example, the third we then get

$$10\times(2/3)-\ \Sigma\ (0/1\ldots.9/10)$$
$$=\ -b_1-a_2+a_3+b_3+\ldots\ldots\ldots+g_3$$

or $2/3=\frac{1}{10}L+\frac{1}{10}\ (-b_1-a_2+a_3+b_3+\ldots+g_3)$ by which the interval 2/3 is determined in terms of the length, L, of the whole bar.

By a very similar process the values of centimetre divisions can be determined when the decimetres are known, and the millimetres in turn when the centimetres are known. The only difference is that since it is impracticable to bring the microscopes so close together that their optical axes lie within one centimetre or one millimetre of each other, it is necessary in these latter operations to compare the centimetres of one decimetre, not with each other, but with those of some other decimetre further along the bar, and the same with the millimeters. The whole process is very direct and simple. But it will be seen that the complete determination of all the subdivisions of a fully divided bar is a very heavy piece of work which is enough to

occupy an observer's full time for many weeks on end.

This method of calibrating a subdivided bar is capable of very high accuracy, since the bar, being a good thermal conductor, maintains itself automatically at a uniform temperature from end to end, and if it is of good homogeneous material it will have the same co-efficient of expansion throughout its length, so that it is immaterial what the temperature is at the moment of comparing any two intervals. Since the motion of the bar is a longitudinal one, it is also possible to use a miscroscope of higher power, since a short focus objective can be allowed to dip into the channel of the bar without interfering with its motion. Provided that the graduation marks on the bar are fine and clear enough to afford good definition under the increased power, these various advantages enable us to obtain appreciably higher accuracy in determining the subdivisions of a divided scale as fractions of its whole length than is possible in comparing two separate scales. In a recent calibration of this kind at the National Physical Laboratory microscopes of five times the ordinary power were employed, and the residuals (observed minus calculated readings) at the end averaged only 0.06μ—not more than one-fifth the average commonly attained ($1\mu=0.0001$ millimetre).

It occurred to me some time ago that advantage might be taken of these facts to obtain a re-determination of the ratio of the lengths of the yard and metre, by a method appreciably more accurate than was used on the last occasion on which it had been done. This project was interrupted by the war, but taken up again after the armistice, and the work has recently been completed, with the provisional result that the metre is found to be 39.370131 inches in length, as against the former value 39.370113 inches, which at present has legal sanction in this country. The previous value was determined with the greatest care in 1895-1896, by Benoit and Chaney, and the difference now found is only one part in two millions—not much more than the possible combined experimental error of the two determinations—which leads to the satisfactory conclusion that the two standards have remained relatively unchanged during the interval of 27 years which has elapsed between the two determinations.

The method is a very simple one, and depends on the fact that the length of the metre is very closely 39.37 inches, which differs by only 0.005 inches from $39\frac{3}{8}''$, or 35 times $1\frac{1}{8}''$, while the yard itself is 32 times $1\frac{1}{8}''$. The bar used was a nickel one, $40\frac{1}{2}$ inches long, divided to eighths of an inch throughout, and the successive intervals of $1\frac{1}{8}''$ (termed spans) were picked out for calibration. Thirty-six such intervals go to the whole length of $40\frac{1}{2}''$, and it is possible to determine the subdivisions in three different ways, dividing first by nine and then by four; first by four and then by nine; or twice by six. It is also possible to calibrate the intervals from 0 to $39\frac{3}{8}''$, and from $1\frac{1}{8}''$ to $40\frac{1}{2}''$ (35 spans each), in two different ways, dividing first by seven and then by five; or first by five and then by seven. In all, therefore, we get seven independent calibrations, from the mean results of which we finally obtain extremely accurate values for the relationship between the five yard intervals, 0 to 36″, $1\frac{1}{8}''$ to $37\frac{1}{8}''$, $2\frac{1}{4}''$ to $38\frac{1}{4}''$, $3\frac{3}{8}''$ to $39\frac{3}{8}''$, and $4\frac{1}{2}''$ to $40\frac{1}{2}''$, and the two approximate metre intervals 0 to $39\frac{3}{8}$, and $1\frac{1}{8}''$ to $40\frac{1}{2}''$. It then remains only to compare these various intervals with the respective defining standards of the yard and metre respectively in order to obtain final value of the desired ratio between the latter.

In building up longer lengths than the yard or metre the first step is to compare, yard by yard, or metre by metre, a longer bar, in a comparator of suitable size for this purpose. The illustration, Fig. 18, shows a comparator built shortly before the war for the Indian Government, by the Cambridge Scientific Instrument Company.

This comparator is capable of accommodating bars up to 4 metres in length, in either of the two tanks shown. The large girder which carries the microscope is hollow, and filled with water to give it great thermal inertia. It is supported on two steel balls at one end and one at the other, arranged on the well-known hole, slot, and plane system, so as to avoid any disturbance of the distance between the microscopes resulting from strains set up by the motion of the heavy carriage and tanks. The larger tank contains two girders, on which two bars may be supported side by side for simple comparison in the ordinary way, or for comparing each 1-metre interval on a 4-metre bar with the length of a known 1-metre standard. This operation, repeated

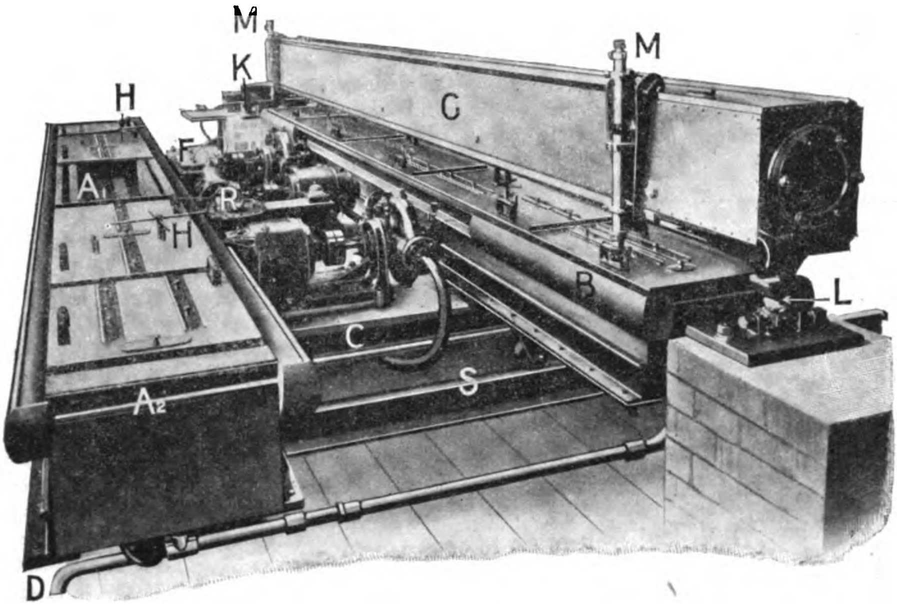

FIG. 18.

for each interval on the 4-metre bar, serves to determine its exact total length in metres, and so provides us with a new standard of considerably greater size, which is used as an intermediate standard in stepping up to the still greater lengths required in standardising the tapes or wires which are used for survey work. The provision of the second tank, mounted on the same carriage with the first, and traversing with it, serves another very important purpose, which is to enable the co-efficients of thermal expansion of the bars to be directly determined.

The larger tank is double, as in the 1-metre comparator described in my first lecture, and the water in the outer bath is circulated by a motor-driven pump through a vessel containing electrical heaters and an adjustable thermostatic device by means of which a constant temperature can be maintained in the tank, to within 0°.01 C. The bar whose co-efficient it is desired to determine is placed in the inner tank, which is brought to a succession of different temperatures in turn. At each temperature it is compared, in the usual way, with a second bar, placed in the smaller tank, and there maintained, by means of crushed ice, at a constant temperature of 0° C. The length of the bar under test is thus compared, at a succession of different temperatures, with another length which is kept unvaried throughout the experiment, and thus its co-efficient of expansion is determined. To secure the maximum invariability of the second bar this is made of "Invar," the special alloy having a very low co-efficient of thermal expansion, discovered by Dr. Guillaume, Director of the Bureau International, Sèvres, which I mentioned in my last lecture.

The question of the variation in the length of standard bars which follow on changes of temperature is one naturally of the very highest importance. I have, however, postponed explaining the methods adopted for determining the effects of temperature until this point, as the apparatus I have just described, though not the only one of its kind in use, is the best example of the type that I am able to show you. When working in a water-bath, as in ordinary comparator methods, the control of temperature, though not very easy where extreme accuracy is required, is none the less a relatively simple matter, as compared with the conditions which obtain where measurements have to be made in air, even under the best of laboratory conditions. When the operations are transferred out of doors, as they are, for example, in determining the length of a base for a geodetic survey, the difficulties become very much greater.

The degree of accuracy to which the temperature of a standard needs to be known, in order to obtain a specified pre-

cision of definition of its length, depends, of course, on the degree of its thermal expansibility, and various materials of which standards may be made differ very markedly in this respect, as may be seen from the following table:—

Material.	Coefficient of Linear Expansion per 1° C.	Used for.
Bronze (Bailey's metal) (16Cu, 2½Sn, 1Zn)	17.7×10^{-6}	Imperial Standard Yard.
Platinum Iridium (90% Pt 10% Ir)	8.7×10^{-6}	International Prototype Metre.
Nickel	12.8×10^{-6}	N.P.L. Reference Standard.
Steel	(about) 11.0×10^{-6}	Engineers' gauges, rules, etc.
"Invar" 36% Ni 64% Fe	(about) 1.0×10^{-6}	Secondary standards for special purposes. 4-metre bar. Surveying tapes. Pendulum rods for clocks.
Fused Silica	0.4×10^{-6}	N.P.L. experimental standard.

You will notice that while all the more ordinary materials have relatively high co-efficients, two materials, "invar" and fused silica, have been found with co-efficients only one-tenth or one-twentieth as great. The first of these, as I have already mentioned, is due to Dr. Guillaume, who made an exhaustive study of the alloys of iron and nickel, and found the very remarkable result that as the percentage of nickel present in the alloy is increased the co-efficient of expansion at first increases appreciably above that of pure iron, then, between 20 and 36 per cent. nickel, diminishes rapidly to an almost negligible amount (one specimen in the possession of the National Physical Laboratory has no measurable thermal expansion at all, and others, particularly rolled tapes or wires on which a great deal of mechanical work has been done, have even been found to have very slight negative coefficients). After this, further addition of nickel to the alloy causes an increase in the coefficient, rapid at first, but slowing down after about 50 per cent. nickel, and then gradually approaching the value for pure nickel.

To the alloy of lowest thermal expansibility (36 per cent. nickel), Dr. Guillaume gave the name "invar," and this material is of very great utility for a number of purposes connected with the accurate control of length measurements under conditions where exact determination of temperature is difficult. Unfortunately, it suffers from two serious defects which render it entirely unsuitable for use as a material of construction for a fundamental standard. In the first place, it is found to grow, rapidly at first, and afterwards more slowly, with lapse of time. A one-metre invar bar in the possession of the National Physical Laboratory has grown, in spite of preliminary artificial ageing by heat treatment, as much as 20 parts in a million during the last 20 years, and is still growing at the rate of nearly half a part in a million per annum. Secondly, an invar bar, on experiencing a change of temperature, does not immediately take up the new length corresponding to the new temperature, but continues to change slowly, according to certain known laws, for a considerable time. The result is that, if the temperature is varying, the length at any moment depends in a complicated manner upon the recent history of the bar.

In a recent lecture before the Physical Society of London, however, Dr. Guillaume announced that he had been successful in discovering a modified form of invar which was secularly stable. I have not yet had any experience of this new alloy, and understand that Dr. Guillaume's experiments are still in progress, but if it has all the virtues claimed, it should prove an extremely valuable addition to the resources of the metrologist.

The other material of very low thermal expansibility is fused silica, the coefficient of which is even lower than that of invar as ordinarily produced in bar form. An experimental one-metre standard of fused silica has been made and has been under observation at the National Physical Laboratory for the last 12 years, during which time no measurable alteration in its length has been observed. The standard takes the form of a tube of vitreous silica, to each end of which is fused a small slab of transparent optical silica, the upper and lower sides of which are ground and polished flat and parallel. The underside of each slab is platinised, and the lines, ruled through the platinum film, are observed through the transparent slab, being so arranged that their virtual images within the thickness of the silica are in the neutral axis. Thin cover plates cemented on the underside of the slabs protect the lines from damage.

A small trunnion piece is fused to the tube at one of the Airy points, and when in the comparator the standard rests on this trunnion, and on a second support beneath the other Airy point, the position of which is etched on the tube. Small holes at either end allow the tube to fill with water so that it sinks in the comparator tank.

Fused silica is, of course, too fragile a material to be suitable for use as a primary standard of length. But the apparent constancy of this experimental bar, of a material so different from that of which the existing primary standards are made, is very good confirmatory evidence that both they and it are free from secular change within the limits of accuracy of the measurements.

It may be worth while at this point to sum up the evidence we have at present for the stability of our existing standards. We have in the first place a number of standards of very different materials and ages, all of which have been compared, directly or indirectly, with the International Prototype Metre, at intervals covering a period of years, and all of which have shown relative agreement, over the period covered, within the limits of experimental error. We may tabulate them as follows :—

Standard.	Material.	Present Age.	Period covered.
Imperial Standard Yard	Bronze (Bailey's Metal)	78 years	1895–1922 (27 years)
N.P.L. Reference Standard	Pure Nickel	22 years	1902–1922 (20 years)
Silica Metre	Fused Silica	12 years	1911–1923 (12 years)

In addition we have comparisons of the metre by the method of optical interference, by Michelson, in 1892, and Fabry et Perot in 1906, an interval of fourteen years, giving the most remarkably concordant results. The periods of time covered by these various comparisons are not, of course, very long regarded from the point of view of scientific history. But the fact that a number of such very different controls agree so closely together constitutes very strong presumptive evidence that each and all of them are actually stable within the limits of our present powers of observation. And as regards the material standards, it is to be remembered that their stability tends to improve with age, so that, with the prototype metre now nearly 50 years old, and an optical control, and possibly also a time control, available, the future constancy of our standard of length measurement now seems well assured.

Referring again to the question of the nickel-iron alloys, I may remind you that by a suitable adjustment of the nickel content it is possible to make an alloy having any desired coefficient of expansion up to 18×10^{-6} per 1° C. And for certain special purposes some of these other alloys are of great utility. The alloy of 58 per cent. nickel, for instance, is quite stable, of good mechanical properties, and capable of taking a very high polish. It has a coefficient of expansion practically equal to that of ordinary steel, and is, therefore, a very suitable material for the construction of secondary standards intended for use in the comparison of industrial scales and gauges, which are usually made of steel. For such purposes it is much more advantageous to have a standard whose temperature coefficient agrees with that of the objects to be compared with it, than one with a very low coefficient differing greatly from them. For in the former case it is only necessary to ensure that the standard and the object being compared are brought to the same common temperature, and the results of the comparison will be correct, without any need for calculation to bring them to standard conditions; whereas, if the standard and the object have different coefficients, it is necessary to know exactly the temperature of each at the time of the comparison, and their coefficients, in order to compute the actual dimensons of the object under examination, when brought to standard temperature. It is always necessary, therefore, to exercise discretion in choosing a secondary standard and to adopt one having the coefficient of thermal expansion best suited for the particular purpose for which it is to be employed.

The use of invar is most advantageous when operations have to be conducted in air, and particularly when, from the nature of the apparatus, it is not possible to bring the two objects to be compared into close proximity with each other, so as to be certain that they are at the same temperature. A typical case, for example, in which it would be appropriately employed, is the operation of transference from line to end measure by means of the machine I first described.

Another case in which it is essential to use invar is in the construction of first-class

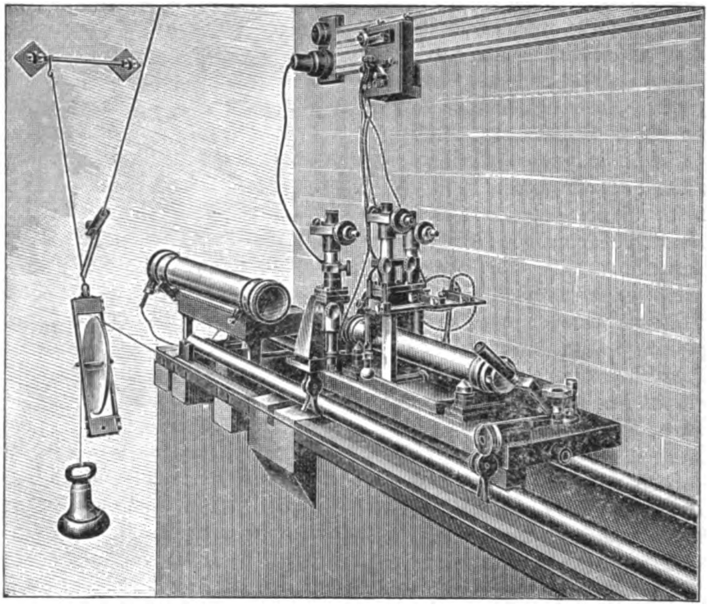

FIG. 19.

surveying tapes and wires, and of the four-metre bar which is used in standardising them. I have described the process by which the four-metre bar is standardised, and its coefficient of expansion determined. The next operation is the standardisation of the mural base, which serves as a second intermediate standard in the verification of the wires themselves. Fig. 19 illustrates one end of the base used for this purpose at the National Physical Laboratory. The whole base is 50 metres in length, and every four metres, as well as at 50ft., 66ft., 100ft., etc., there is a stone block built in, into which is cemented a small polished invar piece on which a small scale is engraved. These scales were carefully ranged in line before they were finally fixed in place, and subsequent tests have shown that they are still true, so that the wall has neither bent nor sagged. Right along the top of the bench there run a pair of parallel rails, which serve to support a light carriage on which the four-metre bar is placed, and also two microscope carriages. Each microscope carriage holds two micrometer microscopes, one of which reads the line on the four-metre bar, and the other the line on the bench mark. Two large fixed collimators, one at each end of the bench, throw parallel beams of light along its whole length, and a telescope on each carriage faces one or other of these collimators, and enables the carriage to be adjusted, no matter where it may be placed along the bench, with the plane containing the two microscope axes always parallel to a fixed plane.

The planes in question will not ordinarily be the same for the two carriages, but any error which might arise from this cause is eliminated in practice by performing one half of the work with the carriages interchanged in position, so that the *mean distance* between the front microscopes, taking the whole operation into account, becomes the same as that between the back ones.

The tapes, or wires, made of invar, are allowed to hang freely, in catenary, between their end graduations, under a certain definite load, usually 10 kilogrammes, which is applied by means of weights hung over frictionless pulleys. This system, which was introduced by M. Jäderin, a Swede, is now almost universally used for first class geodetic work, having entirely displaced the bimetallic bar standard which was formerly used in stepping out bases.

The process of standardisation is as follows:—The tape is first of all hung out along the front of the bench and its terminal graduations are compared with those of the corresponding bench-marks, viewing them simultaneously under the

front microscopes on the carriages. Immediately after this comparison the stepping out of the bench by means of the four-metre bar is commenced, the terminal graduations of the bar being read under the back microscopes and the bench marks under the front microscopes. The bar and the microscope carriages are moved along together, 4 metres at a time, and each 4-interval of the bench is compared in turn with the bar in this way. The usual length of the tape is 24 metres, so that six steps are required. The bench is then again compared with the tape, and after the two microscope carriages have been interchanged in position on the rails, the stepping out process is repeated in the reverse direction. Finally the bench and tape are compared a third time. Means of all the observations are taken and the length of the tape is thus determined in terms of the 4-metre bar. The length of the bench, incidentally, determined but eventually eliminated from the result, is of little value for accurate work, since it varies from time to time, not merely in accordance with its instantaneous temperature, but also depending on its recent temperature history, humidity, and other incalculable causes. All that is required of the bench is that during the time occupied by a complete determination (one whole day) it shall not alter appreciably, or if it alters shall do so at a sensibly uniform rate.

It may be of interest to exhibit the history of the National Physical Laboratory bench since its erection in 1908. The whole bench is 50 metres (about 164 ft.) in length, and in 15 years it has grown, without any sign of cracking, nearly a quarter of an inch; and it is still growing at the rate of about 0.01 inch per year. The upper curve in the diagram, Fig. 20, shows the actual measurements made, and the one below it the temperatures observed at the time the measurements were taken. The dots around the lower (smooth) curve show the results of correcting the actual observations as far as possible for the effects of the instantaneous temperature of the bench at the time, and the smooth curve itself indicates the general trend in the time history of the bench, the general growth, and also a long period fluctuation, summer and winter, being clearly visible. The gap relates to the war period when observations had to be discontinued owing to the pressure of other work.

Recently an interesting new method has been adopted for checking the variations in the length of the bench. Two invar wires, one 50 m. and the other 24 m. in length are suspended in catenary in front of the bench, their ends being firmly embedded in the masonry. These wires have a very low coefficient of thermal expansion (actually it is a slight negative one), and consequently remain practically constant in length, apart from their secular growth, which can be checked from time to time. Opposite the centre of each wire, and vertically below it, a small micrometer is fixed by means

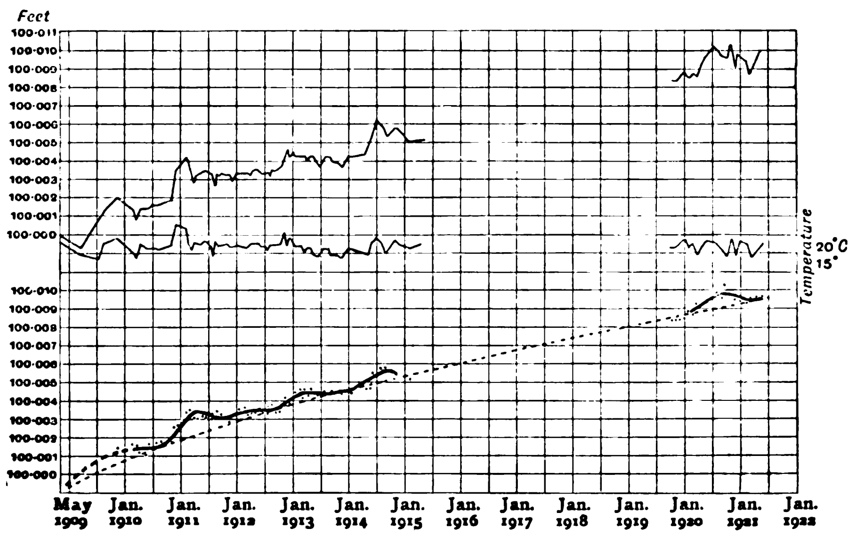

FIG. 20.

of which the sag of the wire can be measured. If the length of the bench increases, the centre of the wire will rise, and vice-versa; and the amount of the central movement is about 12 times the change in length of the bench. Thus, with a simple micrometer measurement taken at the centre of one of these wires it has been found possible to record the variations in the length of the bench from day to day with an accuracy which, on comparison with the direct measurements occasionally made, proves to be something in the order of 1 part in 2 millions.

Such an accuracy is at least as good as, and probably rather better than, that to which the absolute measurements can be effected. Until recently there was a discrepancy, which varied on different occasions from two parts to as much as seven parts in a million between the results of the National Physical Laboratory and those of the Bureau International in the standardisation of the same tapes and wires. As an instance of how difficult it is to trace the sources of such small errors, I may mention that it has taken the last ten years to reach agreement between the two Institutions to an accuracy of one part in a million, as I am happy to say, has now been done. The last outstanding discrepancy was removed in the course of last year as the result of a redetermination, with certain additional precautions, of the base at Sèvres.

In the course of this investigation a considerably simpler method was developed for standardising the tapes at the Laboratory. A 24-metre tape was graduated every 4 metres and was supported, first in a single 24-metre catenary, and then in a series of six consecutive 4-metre catenaries over friction rollers placed at intervals along the bench. In each condition its total length was compared with the bench marks at its ends, and the difference between the single and multiple catenary length thus accurately determined once and for all. The 4-metre bar was put in position beneath the microscopes on the bench and readings taken. The bar was then lowered by means of the adjusting screws on its carriage, and the first 4-metre length of the tape was supported on two small rollers arranged to fit in the channel of the bar, without touching the graduated surface. The tape in its turn was brought into focus under the microscope and readings taken on it, the operation being repeated until sufficient observations were obtained to give a reliable value of the 4-metre length on the tape by comparison with the 4-metre bar. Each of the six sub-divisions of the tape being determined in this manner the whole length, in multiple catenary, is known, and hence the length in single catenary can be obtained by the aid of the preliminary comparisons. This method proved very expeditious, occupying only about 2½ hours for a complete determination as against 9 hours with the collimator method. It has the advantage of being more direct than the latter, and is probably the most accurate method yet devised for standardising these long tapes.

In the tape bench corridor at the National Physical Laboratory there is also a tank—so far as I am aware the only one of its kind in existence—50 metres long, for the purpose of determining the coefficients of expansion of the tapes and wires in their full lengths. The tank is well lagged outside, and the water in it is circulated by means of a pump at the centre, and its temperature can be maintained constant to 0.1° C. throughout its length. The operation ordinarily is a simple one of comparing the length of the tape under test at a number of different temperatures, with that of a standard tape whose thermal coefficient has previously been determined absolutely. The determination of the absolute coefficient of a full length tape is a complicated operation which it would take too long to describe here. But it has been found necessary to do it because invar is not always perfectly homogeneous, and the coefficient of expansion may not, therefore, be uniform from end to end of a long tape, so that to determine the coefficient of a sample piece cut off in the process of manufacture is not sufficient if the highest accuracy of results is desired.

When used in the field the straining pulleys are supported on tripods, while other tripods, unaffected by any strain, serve to carry temporary graduation marks, against which the tapes are compared by means of the scales engraved upon them, and which can be left in place while the tape is being moved forward by a step equal to its own length.

The whole length of a geodetic base, which serves as the starting point for a complete triangulation, is usually 20 kilometres, so that over 800 such steps are

required. In the result extraordinary accuracy of repetition is obtainable, in spite of the difficulties inseparable from open-air work. For the small accidental errors associated with the measurement of each individual step tend to average out in taking the sum, so that the proportionate error in the whole length of the base is only about one-thirtieth that of any individual step. If we suppose a probable error of $\pm \frac{1}{4}$ mm. associated with each step, this is about $\pm$ 1 part in 100,000, and the error on the total length would be only about $\pm$ 1 part in 3,000,000—an amount smaller than the error associated with the preliminary verification of the tape in the Laboratory. This sort of accuracy is, in fact, actually attained in the field (the "probable error" of measurement of the Lossiemouth base, 23,526 ft. in length, determined by the British Ordnance Survey Department in 1909 was actually 1 part in 3,700,000, though the average difference between three independent measurements of any one span was of the order of 6 parts in a million), and sometimes leads the surveyor, who does not always appreciate that the Laboratory part of the work, carried out under what, from his point of view, are such extremely favourable conditions, is, in fact, more difficult than his own, to over-estimate the precision of his final results in respect of the absolute measurement obtained.

Apart from the secular changes which occur in invar, a disadvantage of this material in field use is that it is very easily damaged. It is necessary to coil the tapes on drums of large diameter, and to exercise the greatest care in handling them, or they are liable to get kinked, with consequent alterations in their length. It is, therefore, necessary to return them frequently to the Laboratory for re-determination of their lengths, and this is inconvenient, especially if the survey is in a distant country.

Ordinary steel tape is very much better than invar, both as regards secular stability, and as regards its mechanical properties, and would, therefore, present great advantages if the difficulties of its relatively high thermal expansion and its tendency to rust could be overcome. As regards the latter various methods of surface treatment are available, and it is also possible that a stainless steel tape of suitable mechanical properties might be produced. As regards the former, experiments have recently been carried out at the National Physical Laboratory with some success, on the possibility of actually determining the temperature of the tape when in use in the field, by a measurement of its electrical resistance at the time the readings are being taken. The temperature of a tape exposed in air—particularly under the sun—may be very widely different from that recorded by a neighbouring thermometer, so that if it were possible actually to determine it, and to correct the length measurement for it, the operations of stepping out a base could be carried on much more continuously, irrespective of weather conditions, than is now the case, and improved accuracy might result.

Having shown you how, in respect of line measures, we are able to obtain by stages, from our reference standard, the yard or the metre, both very small and very large measurements, I must now pass from this part of the subject and devote the remainder of this lecture to the comparison and calibration of end-measures.

A number of machines are available on the market which enable the difference between two similar end-measures to be determined. The best known are the original Whitworth machine, Fig. 21, the

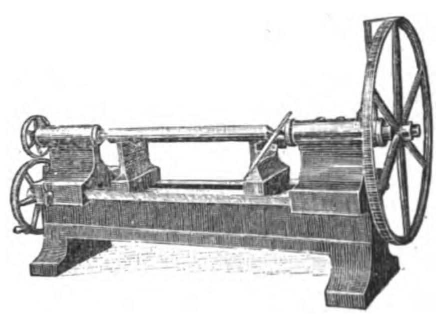

FIG. 21.

Newall machine, Fig. 22, the Pratt and Whitney machine, Fig. 23, and the Société Génevoise machine which I showed you at the beginning of this lecture. All these consist essentially of a bed with supports on which to rest the standard, or the bar to be compared with it; a fixed anvil at one end; a movable anvil, controlled by a micrometer screw, at the other; and some kind of criterion for ascertaining exactly when the conditions of contact are repeated. In the Whitworth machine this takes the form of a small cylindrical gravity piece, which the operator holds in his hand, and

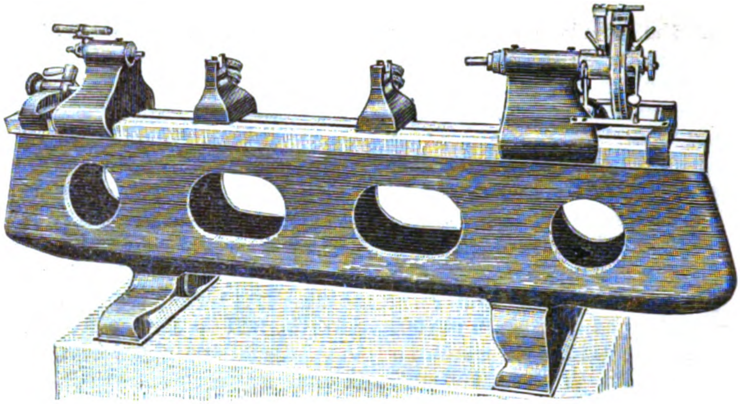

FIG. 22.

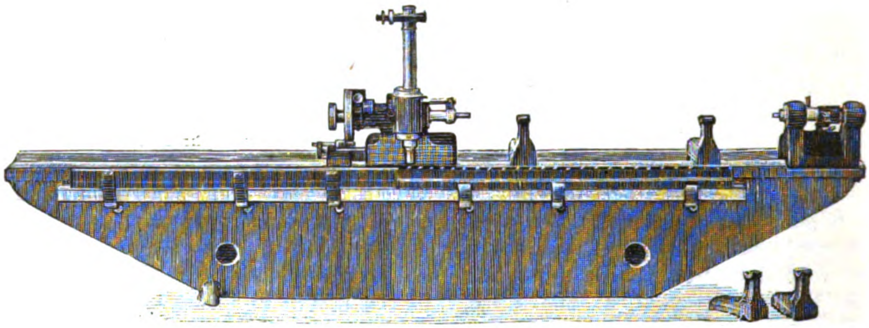

FIG. 23.

feels between the gauge and the movable anvil, feeding the latter forward little by little, until the gravity piece just barely passes through. In the Newall and Pratt and Whitney machines the "fixed" anvil is attached to a plunger pushed forward by a spring, and the slight displacement of this plunger when the bar is pushed against it by the action of the micrometer screw, affords the criterion. In the Newall machine the movement of the plunger tilts a small pivoted level, and the reading of the micrometer is taken when the bubble in the level comes up to a definite mark. In the Pratt & Whitney machine a gravity piece is nipped by the pressure of the spring between two subsidiary anvils, until the slight movement of the plunger releases this pressure, and the gravity piece falls. The operation of comparing two bars on any of these machines is essentially the same. The first bar is placed on the supports, which are carefully adjusted so that its faces are parallel to the measuring faces of the machine; the micrometer is advanced until the criterion of contact is observed; and the reading of the divided wheel is noted. The second bar is then substituted for the first and the operation repeated, and so on alternately until sufficient observations have been obtained.

Great care has to be taken in handling the bars to avoid changes of temperature, and a very interesting machine was devised by Commandant L. Hartmann, of the French Artillery Service, to overcome this difficulty. In this machine, Fig. 24, the two bars to be compared are mounted side by side on a traversing cradle, which operates automatically to place them in position between the measuring faces. When one of the bars is in position the micrometer screw is fed forward by means of a weight attached to a cord passing over a pulley, until contact is made, the pressure at the measuring face being determined by the weight on the cord. Instead of a divided wheel a series of light radial arms are attached to the micrometer spindle, each one of which carries at its end a small needle point; when contact is effected the motion of the micrometer spindle ceases, and a lever moves forward and presses the needle point on one of the arms into a graduated paper

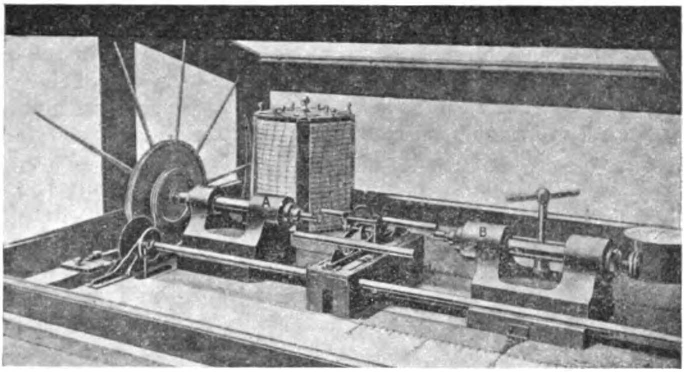

Fig. 24.

chart which is carried on a drum, making a tiny hole. As soon as the needle has been released the continued operation of the machine reverses the motion of the micrometer which screws back to free the bar, which is then lifted by the cradle, carried to one side, and the other bar deposited in its place. At the same time the drum with the paper chart rotates slightly ready for the next impression. The whole cycle of operations is then repeated by the action of the machine as many times as may be required, and finally the paper chart, on being removed, presents a series of dots, arranged alternately in two rows, referring respectively to the two bars, the mean distance between the two rows giving the measure of the difference in length between the two bars. The whole comparison is effected entirely automatically, and the two bars can be placed in position, and left in the closed case of the machine for some hours to attain equal temperature before the action is started. The machine has one marked disadvantage for ordinary purposes, in that the bars must necessarily be spherical-ended, the radius of curvature being equal to half the length of the bar, in order that slight errors in positioning, inevitable with the type of automatic transporter employed, shall not affect the results. Since flat-ended standards and gauges are in much more common use than spherical-ended, this militates against the general application of the instrument.

The machine in most general use for the routine comparison of end gauges at the National Physical Laboratory is a Pratt and Whitney machine, which has, however, been fitted with a special indicator designed and made at the Laboratory. A small mirror is anchored in a horizontal position by two light flexible springs, attached to the back end of the tailstock. A small strut pointed at either end is inserted, slightly below the level of the springs, between the mirror holder and the end of the plunger which carries the measuring anvil. The motion of the plunger when contact is made causes the mirror to tilt upwards, and this tilt is recorded by the motion of a spot of light, with a cross-wire, along a scale placed just behind the machine. The advantages of this indicator are threefold. It gives a very high magnification; it is deadbeat; and it gives a warning in advance when the setting is nearly made, so that the machine can be operated rapidly without fear of over-shooting the mark. In one or more of these respects it is superior to either the gravity piece, or the tilting level, as a criterion.

The machines I have just described, with the exception, perhaps, of the Hartmann Automatic comparator, are intended more for the verification of industrial gauges than for the comparison of important standards. Their accuracy is in every case limited by the fact that the measurement depends upon the direct reading of a micrometer screw, and experience shows that, owing to variations in the thickness of the oil film between the screw and nut, and other causes, repetition of readings closer than about 0.00001 inch is difficult, if not impossible, to attain.

I must now show you two machines, either of which is capable of an accuracy of 0.000001 inch. Both were designed at the National Physical Laboratory, and in neither is there any screw. Both, however, are pure comparators, that is to say, they are capable only of comparing two pieces whose difference in length is small enough

to be comprised within the range of their scales, and they cannot be employed as measuring machines in the sense, for example, of actually measuring the difference between two pieces of appreciably different lengths.

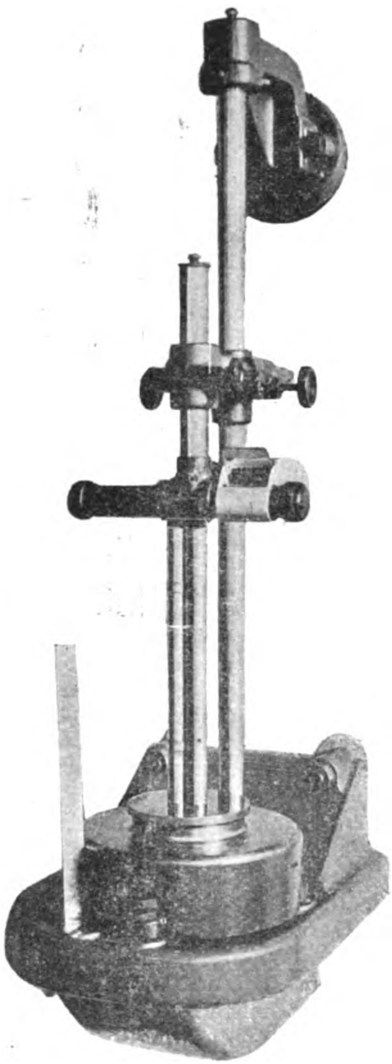

Fig. 25.

The first, Fig. 25, is capable of dealing with end bars or gauges of any length, and was devised by Mr. A. J. C. Brookes, who now holds the patent rights in it. The bars to be compared, which must have accurately finished ends of reasonable size, are wrung down side by side on to the flat upper surface of a turntable carried on a bracket fixed to a rigid wall. This part of the apparatus closely resembles the corresponding part of the lapping jig that I described to you in my first lecture, on which the end-faces of the bars are finished. A vertical rod, whose lower end is carried on the bracket, is fixed to the wall by a second bracket up above, and serves to support the measuring head at any height suitable for the length of the bars to be compared. The measuring head consists of a tube, readily adjustable vertically and horizontally in each of three mutually perpendicular directions, which contains a very sensitive glass level. The level is mounted in a light frame-work, on the under side of which, projecting downwards through a hole in the tube, are two ball feet. The tube is lowered gently until these feet rest upon the upper ends of the bars, one on each. When this occurs the level is entirely released from its supporting tube, except for the action of a small vertical pin, which, resting between two horizontal guides parallel to the axis of the level, prevents it from falling over sideways. In its lengthwise direction it is entirely free to take up its position under its own weight. When it has done so a reading of the position of the bubble in the level is taken, and the latter is then raised momentarily while the turntable, with the two bars upon it, is rotated through 180° about a vertical axis, so that the two bars are interchanged in position beneath the level. A second reading is then taken, in the same way as before, and the difference between the two readings, assuming that the upper surface of the turntable remains parallel to itself during rotation, gives the measure of the difference in length between the bars. If the turntable does not rotate perfectly in its own plane a preliminary experiment, with the level directly in contact with it, serves to determine the correction to be made.

With the balls one inch apart, and a level of 833 ft. (10,000 inches) radius, a difference of level of a millionth of an inch corresponds to a displacement of 0.01 inch on the bubble. This is doubled on reversal, so that one-millionth of an inch difference in length between the bars corresponds to a difference in reading of one-fiftieth of an inch—a readily observable quantity.

The great advantage of this instrument for comparing long end standards is that the indications are independent of any rigid connection between the support of the bars and the measuring appliance, which

depends only on gravity. All that is important is that the lower bracket should be rigid. A second advantage is that the two bars to be compared are set up side by side, in the closest possible proximity to each other, and may be so left to attain a steady and equal temperature before observations are commenced. They are not handled in any way during the observations, which are very rapidly completed.

The second machine is of entirely different principle, with which an accuracy of 0.000001 inch is also obtainable. The action is readily understandable by means of the diagram, Fig. 26. A cast-iron barrel is supported on to the other two, on the end of the long leg of the bell-crank lever. The measuring face is formed on a spindle which passes through a hole in a bush lining the barrel, being held back into a spherical seating by means of a stiff coiled spring. The back end of the bush is split into four leaves, by saw cuts of different lengths, so that two of the leaves are very much stronger than the two opposite to them. Adjusting screws passing through these leaves press on the tail end of the spindle, and by operating these screws the measuring face on the headstock can be adjusted into exact parallelism with that on the tailstock. The latter is formed

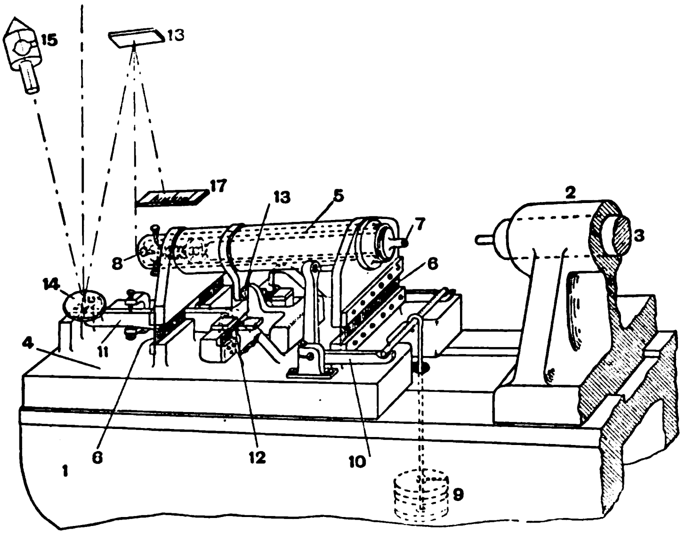

Fig. 26.

flanges at its two ends by means of thin flexible steel strips, running parallel to each other. This allows it freedom of movement without friction in a direction perpendicular to the plane of the strips, but prevents sideway displacement, or angular rotation in any direction. A lug below the barrel carries a flat polished anvil of hardened steel, against which rests a ball set in the short upturned leg of a bell-crank lever. This lever is supported on two pairs of crossed spring steel strips, arranged in such a way as to give freedom of rotation, also without friction, about an axis in the intersection of the planes of the strips. A small mirror table is supported on three ball feet, which rest on guides, composed of pairs of small highly polished cylinders placed in contact with each other, two in line upon the base of the machine, and one, at right angles exactly perpendicular to the axis of a big cylindrical plunger, which is very carefully lapped to be a true fit in the tailstock casting, so that it may be fixed at any desired distance from the face on the headstock without deviating from parallelism, once the latter has been adjusted. Two further bell-crank levers, one on either side serve, by means of struts, to apply a load to the barrel, in such a way that the resultant pressure lies in the measuring axis of the machine. The amount of the pressure can be varied by varying the weight hung upon the small cross-bar which distributes the load between the two levers. A small eccentric, not shown in the diagram, serves to move the barrel against the pressure when required, and thus to release any piece from the machine after measurement.

In use, the piece to be measured is inserted

between the faces, and, the eccentric being turned, the barrel moves forward under the pressure due to the weight until contact is made. As it does so the bell-crank lever rotates slightly, following the movement, and in its turn tilts the small mirror through a much greater angle. This deflects the beam of light from a collimator which, after a second reflexion in a plane mirror overhead, forms an image of a cross-wire on the scale at the back of the machine. The magnification is such that one division of this scale, about $\frac{1}{8}$ of an inch long, corresponds to 0.00001 inch; one-tenth of a division, or 0.000001 inch, is easily observed. The whole machine is shewn in Fig. 27.

A very ready method is available for determining the accuracy of finish of the surface of a gauge, by comparing it by the method of optical interference with a glass proof plane whose perfect flatness has previously been tested. A parallel beam of monochromatic light is directed downwards on to the surface of the gauge, immediately above which, and very nearly or quite parallel to it, is the true surface of the proof plane. Interference is produced between those parts of the beam which are internally reflected at the lower surface of the proof plane and those which, passing on, are reflected in the surface of the gauge. The reflected beam is observed by eye with

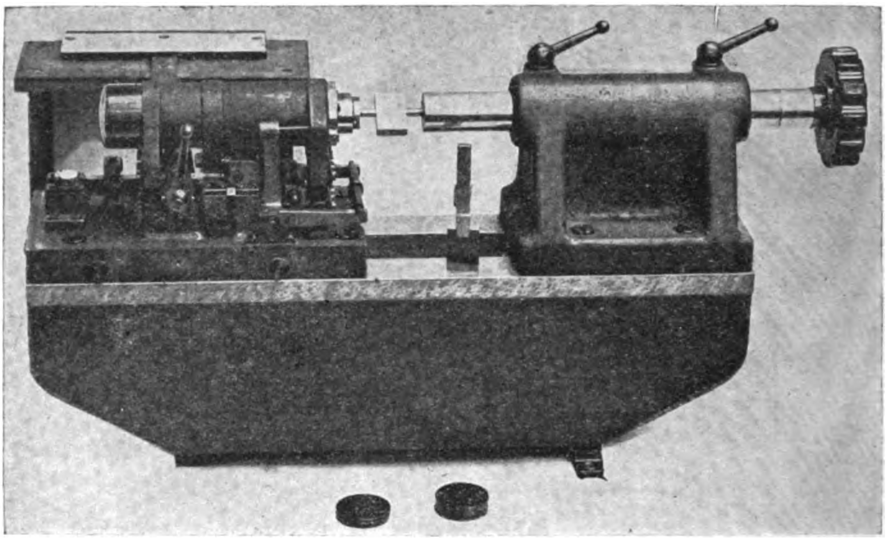

FIG. 27.

the assistance of a glass plate placed at 45° to the vertical, and, since the distance between the proof plane and the gauge is traversed twice by the part of the beam reflected in the latter, the interference bands repeat themselves at intervals corresponding to variations of half a wave-length (if a green light is used, very closely 0.00001 inch) in this distance. The pattern seen, therefore, is a direct contour map of the surface of the gauge, the contours being spaced at intervals of 0.00001 inch in height. It is easy to distinguish a convex from a concave surface by noticing the manner in which the pattern changes as the inclination of the proof plane is varied.

This particular machine is only suitable for short gauges up to 4 inches long, though there is no reason why the mechanism should not be applied to greater lengths. The results obtained with the two different machines, on gauges up to 4 inches, have been found quite consistent, conditionally on the finish of the gauges being sufficiently perfect. It should be noticed that while the level comparator measures locally by the point contact of a ball, the later machine operates by surface contact over the whole area of the measuring face. Unless, therefore, the faces of the gauges are very perfectly finished, the results from the two machines cannot be expected to agree—or, in other words, the gauges cannot be said to possess a defined length to the very high accuracy here in question.

An actual instrument incorporating this principle is shown in Fig. 28. The light is directed down from the inclined mirror at

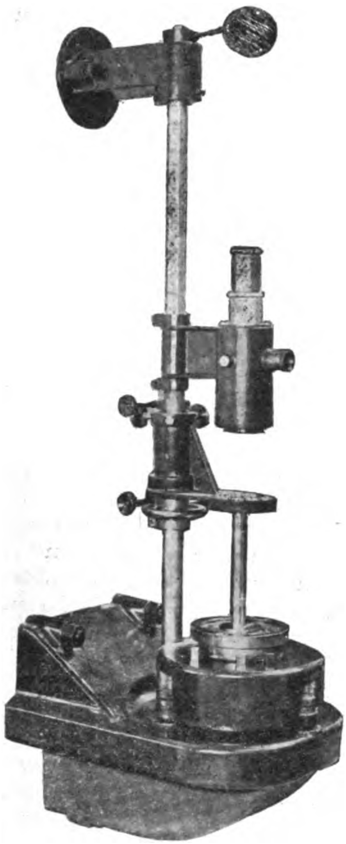

Fig. 28.

the top, and the optical system is arranged in such a way that the fitting containing the lenses, and carrying the proof plane below, can be set to any height to suit the length of the gauge to be examined without necessitating any adjustment of the illumination. The gauge is wrung down on to a turntable, in the same way as on the tilting level comparator, and by observing the changes in the interference pattern as it is rotated, it is possible to determine the parallelism of the two end surfaces, that of the turntable itself having previously been checked. The whole fitting carrying the proof plane can be tilted slightly in either direction by the operation of two micrometer screws.

By wringing two gauges down side by side on such an apparatus, and examining simultaneously the interference patterns produced in each of them, using several different wave-lengths in turn, it is possible to determine directly the difference in length between them to an accuracy also of about 0.000001 inch. This method has recently been developed successfully at the Bureau of Standards, Washington, and is now in regular use there for the routine testing of gauges. There are thus to-day three separate methods available by which this degree of accuracy is readily attainable.

The method of deriving submultiple standards in end-measure is the same in principle whatever type of machine is employed, and while resembling that adopted for line measures in some respects, is essentially different from it, in that generally speaking at least three, and usually four, of the submultiples are involved in each comparison.

In each case the machine is used as a pure comparator, to determine only the very small difference between combinations nominally equal. For symmetry in the work, and ease of calculation, it is convenient if a duplicate set of standards is available. Suppose, for example, we have a set of end bars, 36″, 30″, 24″, 18″, 12″ and 6″, and we wish to ascertain the lengths of all the shorter bars in terms of the 36″. We can then arrange the results of all the comparisons thus :—

12 against						6+6
18	,,				12+6	6+12
24	,,			18+6	12+12	6+18
30	,,		24+6	18+12	12+18	6+24
36	,,	30+6	24+12	18+18	12+24	6+30
36+6	,,	30+12	24+18	18+24	12+30	*(6+36)*
36+12	,,	30+18	24+24	18+30	*(12+36)*	
36+18	,,	30+24	24+30	*(18+36)*		
36+24	,,	30+30	*(24+36)*			
36+30	,,	*(30+36)*				

The entries below the stepped lines are mere repetitions of others entered above it. The entries in italics are "dummies." Then taking for example all the comparisons in the last column but one, relating to the 12″ standard, we get by addition of the results a value for the difference

between $6 \times (12) + (6 + 12 + 18 + 24 + 30 + 36) + (\overline{12} - 12)$ and $2 \times (36) + (6 + 12 + 18 + 24 + 30 + 36)$. The sum of all the gauges disappears from the equation, and $\overline{12} - 12$ is determined by an additional direct comparison of these two gauges, so that we are finally left simply with an equation of the form

$$6 \times (12) = 2 \times (36) + q,$$

or

$$12 = \tfrac{1}{3}(36) + \tfrac{1}{6}q$$

whence the error of the 12″ standard is directly known in terms of the 36″, and the small observed differences of the various, nominally equal, combinations of gauges.

If we take cognizance of the wringing films, we find, more accurately, that this result should really read $12 + t = \frac{1}{3}(36 + t) + \frac{1}{6}q$; and all similar comparisons lead to results in this form. If we consider that the bars are intended to be used by wringing together, and imagine half a wringing film thickness associated with each end of each bar, we see that this is really the relationship we need. It will be remembered that $36'' + t$ was the length of the bar which was determined by Jolly's method.

For the longer standards, such as those mentioned in this example, the tilting level comparator is by far the most satisfactory instrument so far devised. It could not, however, be employed on this class of work were it not for the very high perfection to which, as I showed you, the cylindrical end bars have been brought by the method devised by Mr. Brookes. The surfaces of these bars are so perfect that they will wring together, and when in good condition it is possible to hold out two 18″ gauges, wrung together in this way, horizontally by the end of one of them. For use in the comparator, in a vertical position, a pair of such gauges, wrung together, is as good as a single gauge. And the truth with which the end surfaces are adjusted parallel to each other makes it safe to regard such a combination as having truly the added length of its two components, whereas with less well-finished gauges endless difficulty is experienced in trying to measure two gauges fitted together on account of the imperfections of the faces, and their lack of squareness.

For shorter gauges, such, for example, as the Johansson gauges which I showed you at the beginning of this lecture, the other type of machine, with flat measuring faces, is more usually employed. It was, in fact, designed for this specific purpose.

It may be of interest, as proving that quantities so small as the millionth of an inch (one thousandth part of the thickness of an ordinary cigarette paper) are now really tangible and measurable, to mention that in a recent determination of the inch in terms of the yard, carried out at the National Physical Laboratory by the aid of these two instruments, three different series of comparisons were made, each involving a different series of combinations of the various gauges employed; and the resulting values for each of six different one-inch gauges were in every case in agreement within two millionths of an inch, and mostly within one millionth.

Further, the firm of Johansson has always relied on the National Physical Laboratory measurements as the basis of calibration for all their products in the British system of measures. Not long ago Mr. Johansson sent to the Laboratory from Sweden a 4″ gauge, which he intended using for reference purposes. It was reported on as 0″.000016 too long. Mr. Johansson then made two new 4″ gauges and submitted them to the Laboratory, when their sizes were found to be 4.000002 and 4.000001 inches respectively. Thus it is now possible to attain concordance, not merely of measurement, but of actual adjustment, even between distant countries. Care must, however, be taken to see that such accuracy of measurement is not rendered illusory by secular changes in the gauges themselves. Johansson gauges are used in a large variety of ways for purposes of practical measurements, some of which I hope to describe in my next lecture. During the war, owing to the enormous number of gauges of all kinds which had to be verified at the National Physical Laboratory, the standard gauges were subjected to very severe usage, and were rapidly worn out. A number of new sets had to be obtained and calibrated, and these were put into service, one of them being retained for reference. After a while certain discrepancies became apparent, and these, eventually, were traced to the fact that the new reference gauges were growing rapidly—a circumstance which the older gauges had given no reason to anticipate.

Fortunately, the discrepancies were noticed in time, and no serious consequences ensued, although the amount of the change was considerable, and the growth has since been continued.

Secondary standards of this kind are almost of necessity always made of hardened tool steel, a substance particularly liable to secular change, on account of the internal strains set up during quenching. It is, therefore, very important, especially in the case of the longer bars, that the most careful attention should be given in their production to securing the particular conditions of thermal and other treatment best suited to minimise this trouble. The problem has received attention from many experimenters, but, so far, no absolutely certain means of eliminating secular change has been found. Some success has been attained, however, according to the results of tests recently made on certain 4″ specimens recently tested at the National Physical Laboratory, after hardening with and without special treatment.

In the case of longer bars, even if a treatment entirely suitable for shorter specimens could be found, it is extremely difficult to ensure uniform conditions at all stages of treatment, throughout the whole length. It appeared better, therefore, to seek a means for hardening a short length only, at either end of the bar, leaving the rest of the length in a "normalised" condition. Ordinary case hardening on a mild steel bar is not suitable, as the unhardened part of the material is too soft and liable to damage. With an apparatus recently constructed at the Laboratory it has, however, been found possible to obtain completely successful hardening of, say, ¼″ only at each end of a long bar of tool steel. The method employed is to immerse the bar vertically in a water bath to within about two inches of its end, on which a pad of graphite is placed, in as intimate contact as possible. Above this are two further graphite pads, of which the upper one is in intimate contact with the lower end of a bar connected to a heavy copper lead, while the intermediate one is convex on either side, and makes point contact only with the two outer pads. The lower end of the bar to be hardened dips into a mercury cup at the bottom of the bath, and through this is connected to a second heavy copper lead. When all is ready a low voltage electric circuit is connected through the leads and a heavy current (about 600 ampères) passes through the bar and through the graphite pads. Intense local heating takes place at the point contacts between the latter, and they rapidly attain a bright red heat. The temperature is uniformly distributed by conduction throughout the substance of the graphite, and transmitted to the end of the bar. After a minute or so the end of the bar reaches a hardening temperature, when it is allowed to fall by its own weight into the water bath, breaking the circuit as it does so.

The result is that the end of the bar is hardened uniformly over its whole surface to a depth depending only on the current employed and the length of time that it is allowed to pass. Subsequent thermal treatment may, of course, still be resorted to in order to minimise secular change in the hardened portions. But these constitute so small a proportion of the whole length that the whole effect is in any case reduced to relatively small importance.

A series of new end standards are now to be made, with ends hardened in this way, and it is anticipated that these will still further improve the accuracy obtainable in measurement. At present, bars of differing lengths almost inevitably reach different conditions of hardening owing to unavoidable variations in thermal treatment, and this results in varying coefficients of expansion. With the new bars by far the greater part of each will be in the "normalised" condition, and the coefficients of expansion therefore, are expected to be much more nearly alike, with resulting improvement in the accuracy of the comparisons made between them.

I have shown you how the submultiple end standards are derived from the primary standard in the form of bars or blocks with flat parallel opposed faces. Before leaving this part of the subject I must also deal briefly with the methods used for standardising cylinders and spheres. A cylindrical gauge may be directly measured in any of the ordinary types of measuring machine which I described to you just now, by direct comparison with an end gauge (or Johansson combination) of approximately the same size. There are, however, two precautions which must be observed. First of all, care must be taken to see that the faces of the measuring machine are exactly parallel to each other, and if one measuring face rotates with the micrometer screw, as in the Newall machine, that this parallelism is maintained in all positions of the screw. Otherwise, the faces will have a chance to approach relatively nearer when the cylinder is in place than they can

do when it is not, and the measurement obtained will be too small.

Secondly, measurement in a machine in this way is not in itself sufficient to prove that the cylinder is round. During the war it was found that cylindrical gauges of sufficient accuracy for a great many purposes could be obtained at a very reasonable cost by selection from the standard rollers manufactured by Messrs. Hoffmann, Limited, for use in roller bearings. One day, however, it was discovered that one of these gauges refused to enter a hole known by measurement to be larger than itself. On investigation it was found that the gauge in question, instead of being round, was lobed as indicated in the diagram, Fig. 29, from which it can be seen at once

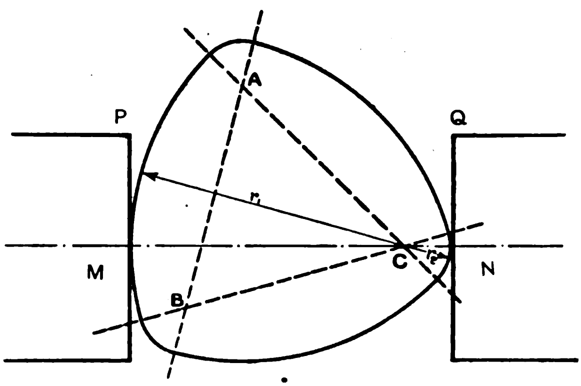

Fig. 29.

that while its size, as measured between two parallel planes, is the same in all directions, being simply the sum of the smaller and greater radii, yet its effective size is appreciably greater. To ensure, therefore, that a cylindrical part is properly measured, it is necessary not only to measure its apparent diameter in the measuring machine, but also to check its shape in some way. This may be accomplished by resting it in a vee-block, and with some kind of indicator bearing upon it at a point opposite to the bottom of the vee, observing any variations which may occur as it is slowly rotated in the vee. If it is perfectly cylindrical no variations will, of course, appear. Otherwise the amount of the variation serves as a measure of the error. This same kind of lobing was also found, more recently, in some very small cylinders (only about 0".006 in diameter) specially made at the National Physical Laboratory for the purpose of measuring the effective diameters of small B.A. screw gauges, by a method which I shall be describing in my third lecture. The cylinders were produced by lapping between flat plates, and by measurement appeared perfectly uniform. But certain peculiar results obtained in measuring gauges with them led to the discovery of the lobing, and a new process of manufacture had to be evolved in order to avoid it. Any odd number of lobes may occur, three, five and seven having all been actually observed, though the higher numbers are much less common. A little consideration of the geometry of the diagram will show that an even number of lobes is not possible without actual variation in diameter.

For the measurement of very large cylinders—up to 21" diameter—a special machine has been set up at the National Physical Laboratory, which is illustrated in Fig. 30. In this machine the object to be measured is mounted on centres between two opposed measuring headstocks carried on a cross-girder. Each headstock contains a barrel, which can be moved in and out by a micrometer screw operated by a large divided wheel. In the body of the barrel is pivoted a pendulum piece, to the upper end of which a level is attached. The measuring face is on a loose plunger, sliding in the barrel, and bearing by means of a small knife-edge at its inner end against a vertical hardened flat face on the stem of the pendulum at a point just below the pivot. To take a reading the barrel is advanced slowly by means of the micrometer screw, until a point is reached when the measuring anvil makes contact with the piece being measured. The motion of the plunger is then arrested, and any

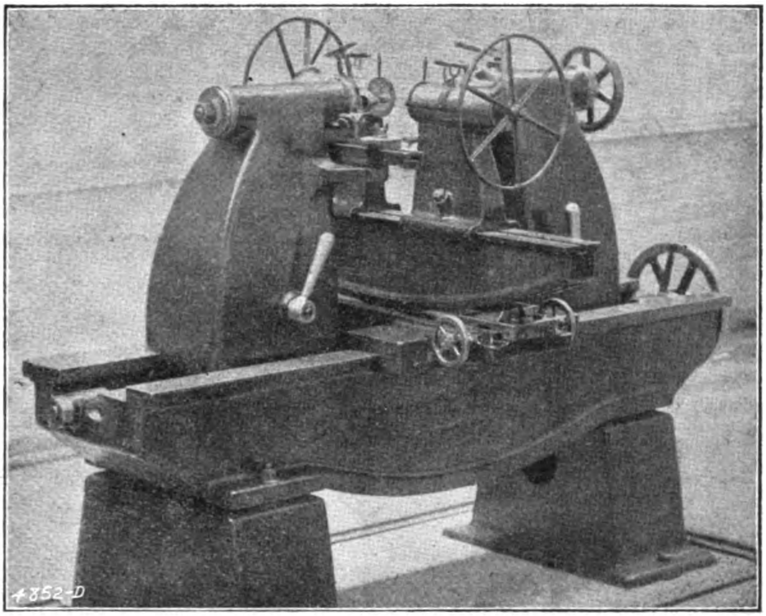

FIG. 30.

further advance of the barrel under the action of the micrometer screw has the effect of pushing the knife-edge against the stem of the pendulum, and so tilting the latter, and with it the level. When the bubble in the level reaches a certain mark the reading of the divided wheel is observed. Both headstocks are used together, and the sum of the two readings has to be taken in order to get the diameter of the object under measurement. The cross-girder with the two headstocks rests on three feet in a hole, slot, and plane arrangement on a slide which can be traversed along the bed of the machine. One of the main centres is pierced by a horizontal hole, and a standard end bar of approximately the same size as the diameter under measurement passes through this hole, and rests on two vee-brackets attached to the main support. Readings are taken alternately, by traversing the saddle, on the test object and on the end bar, and the difference between the sums of the respective readings gives the measure of diameter required. The micrometer screws are of one-twentieth inch pitch, and the wheels are 12″ diameter with 500 divisions reading by vernier to one-tenth division, or 0.00001 inch. It is found perfectly easy to repeat readings to this accuracy provided the temperature conditions are properly controlled. The machine was designed specially for the purpose of measuring the diameters of standard electrical inductance coils, wound with bare copper wire in spiral grooves cut on the surface of marble cylinders. Since in this case the contact takes place at a single point, instead of being distributed along a line or over a surface, it was necessary, in order to minimise errors due to temporary elastic deformations at the point of contact, to reduce the measuring pressure as much as possible. The pendulum mechanism is very advantageous in this respect, as it is possible to adjust it so that no more control is given than is necessary to overcome the sliding friction of the plunger. The actual pressure at the contact during measurement can be reduced as low as four ounces.

The question of elastic compression at a point contact becomes very important in the measurement of spheres. These can be dealt with otherwise in the same manner as cylinders, and very much the same remarks apply. But the contact pressure in the most ordinary measuring machines is of the order of 4 to 5 lbs., and this is sufficient to cause a very considerable deformation at the contact of a flat measuring face with a sphere, which does not occur when the comparison measurement of the flat-ended standard is made. In this

way appreciable errors may be introduced into the supposed measurements of spherical gauges.

The theory of elastic compression at a contact has been fully worked out by H. Hertz, who gives a formula equivalent to

$$0{\cdot}00003\ P^{2/3} \times (1/D)^{1/3}$$

as the total compression effect on a steel ball of diameter D, when pressed with a force P between two flat steel faces. The formula includes the compression of the ball, and also of the faces at both points of contact.

At the National Physical Laboratory the measurement of spherical gauges is now done on the "millionth" comparator, which I described to you earlier this evening. This has two advantages over ordinary measuring machines. One is that a very delicate adjustment for parallelism of the measuring faces is provided, so that errors are not likely to be introduced from this source in transferring from the flat-ended reference standard to the sphere. The other, and still more important, advantage is that the pressure at the contact can be varied at will, and is definitely known, depending solely on the load put on the weight pan. Consequently corrections, based on Hertz' formulæ, can be applied to the readings with confidence.

In order to check the truth of the formulæ a number of tests have been made, using different loads on the pan, and the results when plotted, not only serve to prove the accuracy of the formulæ, but also give an idea of the amounts of the corrections required in various cases.

For a 1″ steel sphere, under a pressure of 2 lbs., the total amount of the compression—*i.e.*, the mutual approach of the flat measuring faces of the machine after the first contact without pressure—is about 0″.00005, while for a 0.″05 diameter cylinder, between flat measuring faces ¼″ diameter, it amounts to about 0.″000008 only.

Steel balls, used as gauges, are in many respects remarkably perfect. They easily fulfil the maker's guarantee of accuracy to within 0.″0001 of size, and are generally spherical within less than half this amount. But they are apt to vary slightly from perfect spheres, and have sometimes odd high spots which one only encounters occasionally in measurement, but which are undoubtedly there when found. It is necessary, therefore, if it is desired to use such balls for reference purposes to fix definitely the particular diameter along which the measurement is to be made. To secure this each reference sphere is mounted in a ring, which is flexibly hung by means of two small chains, from a small cross-bar which can be suspended from a cradle on the machine, in such a way that the ball is perfectly free to set itself always in one definite direction for measurement. The cradle runs along a small ball race, so that the whole can traverse in the direction of measurement, and thus move freely into position between the measuring faces.

OBITUARY.

Charles J. Wild.—Mr. Charles J. Wild, of Messrs. Reeves & Sons, Ltd., manufacturers of artists' and draughtsman's colours and materials, died on September 20th. He was an influential member of various societies, such as the National Union of Manufacturers; but, owing to his retiring nature, he did not take any prominent part in public life. He was widely known, however, as possessing a very sound knowledge of his business, and was frequently consulted by artists on questions concerning their media.

His family have been engaged in colour manufacture for seven generations. His great-great-grandfather, William Reeves, was awarded the "Silver Pallet" of the Society of Arts for the invention of cake water colours in 1781, and his family has for many years been represented on the list of Fellows of the Society. Mr. Wild himself was elected a member in 1894, and his place will be taken by his nephew, Mr. A. G. Simmons.

J. Herbert Tritton.—Mr. Joseph Herbert Tritton, the well-known and much-respected City banker, who died on the 12th ult., in his eightieth year, was a Fellow of the Society of long standing, he having been elected in 1890. One of the founders of the Institute of Bankers, he enjoyed the distinction of being the only man chosen for two distinct periods to serve as its President. He was formerly a partner in Messrs. Barclay, Bevan, Tritton & Co., a Director of Barclays Bank, Chairman of the Indo-European Telegraph Co., Member of the Council of Foreign Bondholders, Honorary Secretary, London Clearing Bankers, and President of the London Chamber of Commerce. He was decorated with the Persian Order of the Lion and the Sun.

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FRIDAY, OCTOBER 19, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICES.

OPENING OF THE 170th SESSION.

The Opening Meeting of the 170th Session will be held on Wednesday, November 7th, when an address will be delivered by Lord Askwith, K.C.B., K.C., D.C.L., Chairman of the Council, on "Exhibitions." The Chair will be taken at 8 p.m.

SOCIÉTÉ D'ENCOURAGEMENT POUR L'INDUSTRIE NATIONALE.

The Council, at their last meeting on October 8th, elected M. L. Baclé, President of the Société d'Encouragement pour l'Industrie Nationale, a Life Fellow of the Society under the terms of Section 61 of the By-laws.

The Société d'Encouragement pour l'Industrie Nationale celebrated the 122nd anniversary of its foundation in June last. The Royal Society of Arts was represented on the occasion by Mr. C. F. Cross, F.R.S., who presented an address of congratulation, signed by H.R.H. the Duke of Connaught and Strathearn, K.G., President of the Society, and Lord Askwith, K.C.B., K.C., D.C.L., Chairman of the Council.

The Société is modelled to a very large extent on the lines of the Royal Society of Arts, and it is the hope of the Council, as stated in the last Annual Report, that a definite link may be created between the two kindred bodies.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

PRECISE LENGTH MEASUREMENTS.

By J. E. Sears, Junr., C.B.E., M.A., M.I.Mech.E., A.M.Inst.C.E.

Superintendent of Metrology, National Physical Laboratory, and Deputy Warden of the Standards.

Lecture III.—*Delivered March 19th*, 1923.

SOME PRACTICAL APPLICATIONS.

In my last lecture I showed how our reference and working standards, of end-bar, Johansson block, cylindrical, or spherical type, are derived and standardized from the primary standard. I propose now to consider the application of such standards in the measurement of other objects of more complex form, and some other special machines and appliances designed for use in such work.

I may well begin this part of my subject by reference to some of the many uses to which block gauges of the Johansson type may be put. You will remember that I described how with the aid of these blocks it was possible, by wringing together in suitable groups, to build up combination gauges of any desired length correct to the nearest ten-thousandth part of an inch. Typical cases in which Johansson gauges will be found serviceable include :—

Measurement of conical plug gauges.

Checking of plain plug gauges between limits.

Scribing lines on plate gauges, at predetermined distances from their edges.

Measurement or adjustment of angles.

Checking height of steps on plug gauges.

Measuring diameters of ring gauges.

Measuring openings of snap gauges.

Measuring form of head gauges for shell.

Checking various dimensions on position gauges for fuses, etc.

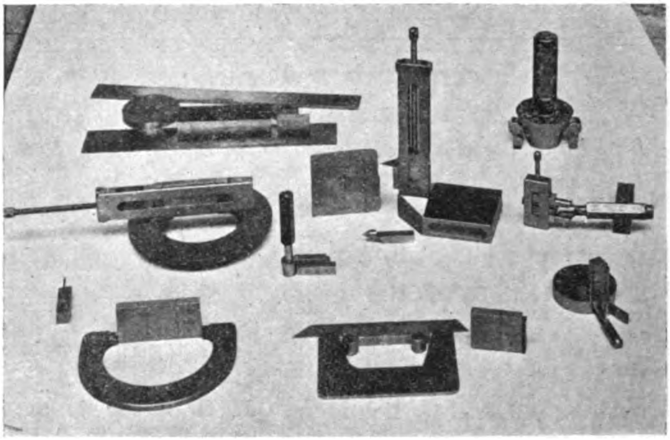

FIG. 31

The methods involved in some of these operations may be described briefly with the aid of Fig. 31. In measuring a conical plug, roller gauges are used in addition to the block gauges, and measurements are made with a micrometer over the rollers, placed on pairs of blocks of various heights, on either side of the cone, and resting on a surface plate on which the latter also rests. These measurements, with a knowledge of the sizes of the blocks and rollers used, are sufficient to enable the taper of the cone to be determined, as well as its diameter at some definite position along its length—*e.g.*, where it meets the plane of the surface plate. To see whether it is symmetrical an adjustable set square may be used, with the stock resting on the surface plate and the blade set to the semi-angle of the cone. If the blade touches the generators of the cone equally all round its axis must be perpendicular to the end on which it rests.

The measurement of a conical ring gauge is very similar, except that spherical gauges must be substituted for the rollers, and the dimensions are obtained by measuring the heights at which different sized spheres rest in the cone. Where a spherical gauge of suitable diameter is not available, it is possible to get over the difficulty by the aid of a small cylinder whose size is known, and which is inserted in the cone together with the nearest convenient size of sphere.

The test of a snap gauge is, of course, quite direct, consisting simply of trying in the jaw successive combinations of Johansson gauges of slightly differing amounts, until that combination is found which exactly fits. It is, however, not too easy to say exactly when the fit is obtained, as owing to the very springy character of a snap gauge it is usually possible to find several combinations differing amongst themselves by several ten-thousandths of an inch, any one of which will enter the jaw freely, but without shake. The criterion usually adopted is to lay the Johansson combinations in turn on a surface plate, try the gauge over them and to accept as the size of the gauge that of the smallest combination which will enter it without shake. Generally speaking, the gauge will move such a combination about on the surface plate, but will not lift it clear.

A similar difficulty arises in measuring plain ring gauges, if they are tested by the simple and direct method illustrated in Fig. 31. The pressure of the feeler points is quite sufficient to deform the ring into an oval, and so to give an over-estimate of its actual size. Even if the ring be tested by a solid plug gauge the difficulty is not entirely overcome, for the whole ring will stretch to accommodate a plug appreciably bigger than itself, as may be proved by measuring the outside of the ring before and after insertion of the plug. I have on the table a plug and a ring gauge specially prepared for the purpose of demonstrating this. The ring, by accurate methods of measurement which I will describe later, is known to be about 0.0001 inch smaller than the plug. Yet, with plenty of lubricant, I have no difficulty in passing the plug through the ring by hand, and the outside of the ring expands by nearly 0.0001 inch as I do so, showing that the whole ring has

been stretched. The experiment will not succeed without the lubricant, and if it is desired to determine the size of the ring in this way the plug and ring should be tried together quite dry. If under these conditions the plug enters and fits the ring without shake, it may confidently be said that they are very closely of the same size. But the experiment is a risky one, for if the plug is the least bit larger than the ring, or if there be a speck of dirt present, the plug will probably seize in the ring, and it will be impossible to separate them again without seriously damaging both.

With large, and consequently relatively thin, ring gauges—such as those used for checking the diameters of large shell—it was found during the war that the possible amount of stretch in forcing a well lubricated check gauge through was of the order of 0.001 inch, practically equal to the tolerance allowed on the gauge. Another method had, therefore, to be sought, and that eventually used in testing many hundreds of gauges of this kind is indicated in Fig. 32. The

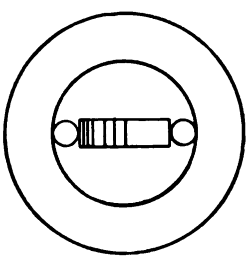

Fig. 32

ring to be tested is laid on a surface plate, and a pack of Johansson gauges and two cylindrical gauges are used. So long as the combined dimensions of the Johansson pack and of the two cylinders is less than the diameter of the ring it will be possible to roll either of the cylinders backwards and forwards round the periphery of the ring through a distance which serves as a measure of the "slack." The size of the ring is intermediate between that given by the last combination which permits such motion, and the first which will not. It is thus definitely determined within one ten-thousandth of an inch. The method also enables us to see whether the ring is oval, which the check plug method does not, as the ring even if it does not need to stretch bodily, will easily alter its shape to accommodate a plug of the same mean diameter as itself. I shall describe later one or two methods for measuring rings still more accurately. None of these methods serve to detect a trilobed ring similar to the lobed plug which I described in my last lecture. To do this some special arrangement would be necessary. One such arrangement is provided by the three-legged micrometer manufactured by the Newall Engineering Company. But the very feature which makes this instrument suitable for detecting a trilobe formation renders it insensitive to the oval, or bilobe, shape. And in the case of rings the latter is far more likely to be present—as the result for example of spring when released from the machine, or of warping after hardening—than is the former.

Certain simple forms of profile gauges can also conveniently be measured by means of Johansson gauges and cylinders. Fig. 31 illustrates how this may be done in the case of a "Form of Head" gauge for shell. The gauge is laid on a surface plate, with its bottom end in contact with a straight edge. By the use of cylinders and Johansson gauges in the manner indicated the width of the gauge at any distance from this straight edge can be determined. To test for symmetry the two diagonals should also be measured, which can be done in a similar manner.

Very frequently, however, profile and other gauges of much more complicated design, such, for example, as form of driving band gauges, need to be verified. Large numbers of these gauges had to be verified during the late war, and though it is possible to deal with an individual case by direct methods of measurement, these become very laborious, and are out of the question when quantities are to be measured. The method was first tried of dealing with a counter-part, or check gauge, by direct measurement and comparing all other gauges with this by fitting them together and viewing the accuracy of fit against an illuminated background. It was soon found, however, firstly that it was extremely difficult to get a check made with such accuracy that it could fairly be used in this way to criticise other gauges, and, secondly that even when the check was obtained it was extremely difficult to tell a manufacturer of gauges what alterations were necessary in order to correct any faults observed and render his gauges accurate.

Other methods were, therefore, sought and through the persistence of Mr. E. M. Eden, then on the staff of the Metrology Department, but now a member of the General Electric Co.'s Research staff at their new Wembley Laboratory, the optical apparatus which has since become widely known under the name "horizontal projector" was developed. The great feature of this machine consists in the combination of optical components adapted to give a uniform undistorted magnification over a field of view of considerable size. I had previously suggested something of the kind, but optical experts pronounced it impracticable, and the suggestion was accordingly abandoned. Mr. Eden took it up again, and by actual experiment with a large number of different combinations eventually succeeded in obtaining one which gave satisfactory results over a field of about 1¾ inches diameter, with a magnification of 50 times, so that the enlarged image is about 7 ft. 6 ins. in diameter.

a carriage which moves in a longitudinal direction on guides on the base plate, being controlled from the distant screen by means of a small eccentric arrangement, through the two cords shown. This enables slight adjustments of the object for focus to be made, and the whole apparatus is fixed so that the projecting lens is at such a distance from the screen that, when perfect focus is secured, the magnification is exactly 50 times. The magnification and the uniformity of the field can be tested by measuring the diameter of the image of a small cylinder of known size at different portions all over the illuminated circle on the screen.

You will notice that in Fig. 33 a small profile gauge is shown in position on the apparatus. The next illustration (Fig. 34) shows the actual appearance of this gauge on the screen. To determine the errors, if any, which may be present in the gauge, a diagram of the correct profile is first carefully prepared, exactly 50 times full

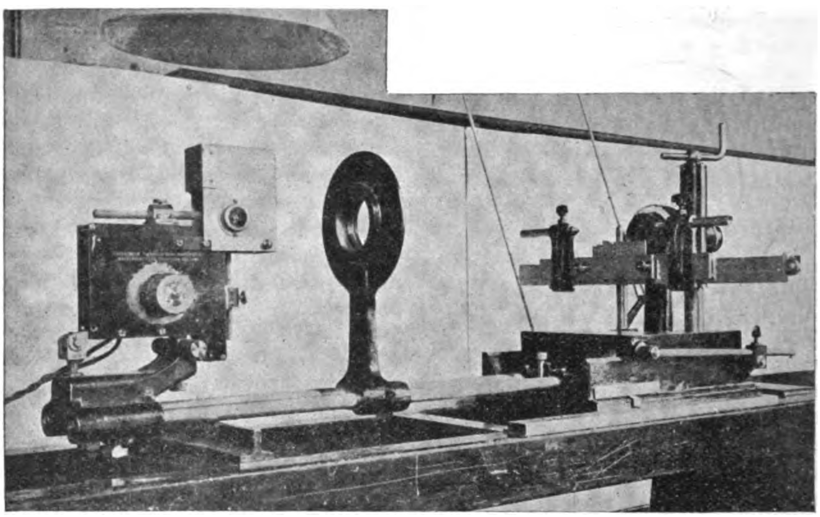

Fig. 33

Fig. 33 shows the instrument as finally designed. Light from an arc lamp, shown on the left of the figure, passes through a condensing lens, by which it is converted into a parallel beam which is directed towards the combination projecting lens. The object to be examined is held in the path of this beam on a small cradle which can be slid transversely along a bar supported from a column up and down which it can be given a vertical motion by means of a screw adjustment. This column is fixed to

size, in the drawing office, on white Bristol board. Paper is unsuitable because it is liable to stretch and vary with the state of the atmosphere. The diagram is pinned to the screen, which can be raised or lowered, traversed sideways, or rotated in its own plane, until any suitably selected portions of the image are made to coincide with the corresponding lines on the diagram. The errors at other points can then be actually measured, on a scale of 50 to 1, by means of an ordinary divided rule. An error of

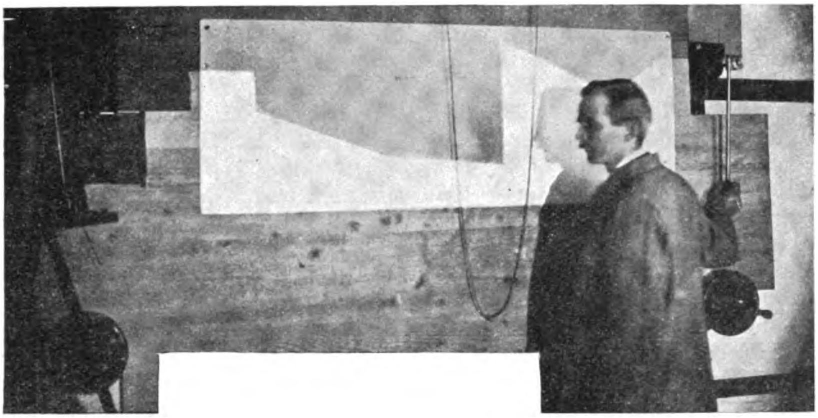

FIG. 34

1/1,000th inch is represented by 1/20th inch on the diagram, and it is easily possible to read the errors to about 1/5000th inch. To ensure that no mistake in magnification is made, either by faulty positioning of the machine or adjustment of focus, or by stretching of the diagram, it is usually advisable, if the object being inspected is of considerable size, to check some convenient leading dimension by mechanical measurement. In the case illustrated the whole width of the broad tongue, between the two parallel edges, could be so checked.

The general arrangement of the horizontal projector provides for its application also to the inspection of the thread form of a screw gauge. For this purpose it is necessary that the beam of parallel light shall be directed, not along the axis of the machine, but along the "rake" of the thread. To make this possible the frame carrying the arc lamp and condenser lens is pivoted about the foot of the column which supports the projecting lens, so that, whatever the angle at which it may be set, the beam will always fill this lens. If the light is not directed along the rake, portions of the thread in front of, or behind, the diametral plane which is focussed on the screen, interfere with the passage of the beam, and so falsify the resulting image. A complete theory of the nature of the image under these conditions is so far lacking, but it appears to partake partly of the nature of a shadowgram, and partly of a truly focussed image of the diametral plane, which, of course, is the desired result. It is only if the light is properly directed along the rake that the shadowgram and the focussed image can truly coincide.

The horizontal projector has now been largely superseded, for purposes of screw thread measurement, by the much more generally convenient and comprehensive vertical type, specially designed for that work, which I shall describe to you later. It is still, however, the more convenient instrument to use for the examinaton of plaster casts, taken from the interior of ring screw gauges, in order to obtain an objective view of their thread forms. In this connection it is frequently necessary to measure the deviations of the projected image from the standard profile to special accuracy, since only one side of the gauge is represented, and any error in the estimated relation between different parts of the thread form is multiplied by two when referred to the diameter of the gauge. With this in view the screen of one of the smaller projectors at the Laboratory has been modified so as to rise and fall on a micrometer screw adjustment, so that first one portion and then another of the projected image can be brought into exact register with the corresponding part of the diagram. In this way the relative errors at different places can be measured with considerably enhanced precision. The pitch of the screw is 1/10th inch and one whole turn of the micrometer wheel, therefore, corresponds to 1/500th inch the object being examined. The wheel is 6 inches in diameter, with a periphery of, roughly, 20 inches, so that a division of 1/10th inch in this wheel represents an actual measurement of one hundred-thousandth of an inch. The optical system in this particular apparatus is not required to fill a very large field of view, and, therefore, more attention can be paid to its perfection in other respects. Thus, although it still falls far short of the very exceptiona

accuracy which such an arrangement would otherwise render possible, a distinct advance has been achieved, for it is found possible, with small objects giving crisp definition, to repeat measurements within an accuracy of a few hundred thousandths of an inch, as compared with nearly ten times that amount, which is the limit attainable by a direct scaling of the discrepancies between the image and the diagram.

I must now turn to the subject of screw thread measurement. But before discussing the methods and apparatus employed, it is necessary to define certain terms which are used to describe the various elements of a screw, and which will be continually recurring in the description. The following are the principal definitions required, and apply to ordinary vee threads, such, for example, as the standard Whitworth threads. The "full" diameter is the maximum diameter, being the crest diameter of a plug screw, or the root diameter of a ring screw. The "core" diameter is the minimum diameter, being the root diameter of a plug screw, or the crest diameter of a ring screw. The "effective" diameter is difficult to define well. The definition usually given, and which will serve our immediate need, is the length of a line, drawn perpendicular to the axis of the screw, and terminated at either end by the parallel flanks of the threads. If the effective diameter is small the threads on a plug screw will be thin; on a ring screw they will be thick. If the effective diameter is large, the threads on a plug screw will be thick, or those on a ring screw thin. The "pitch" is the distance between corresponding points on successive threads, measured parallel to the axis. The "angle" is that contained between the straight parts of the flanks, or slopes of the threads.

Commencing with the measurement of plug screws, which are much more easy to deal with than rings, the full diameter is readily measured in any ordinary measuring machine or micrometer, and calls for little comment. Care must be taken, since point contacts are involved, that no undue pressure is exerted in measurement. The core diameter is measured by means of vee pieces of hardened steel, finished to a smaller angle, and with a smaller radius along the edge than those of the screw to be measured. The back of the vee-piece is carefully lapped flat and parallel to the radiused edge, which should be quite straight. The vee-pieces are hung vertically by light threads, and are set first of all against a plain cylinder of known size, and then in turn, in the roots of threads of the screw to be measured, one on either side, as indicated in Fig. 35. In each case the overall measurement is

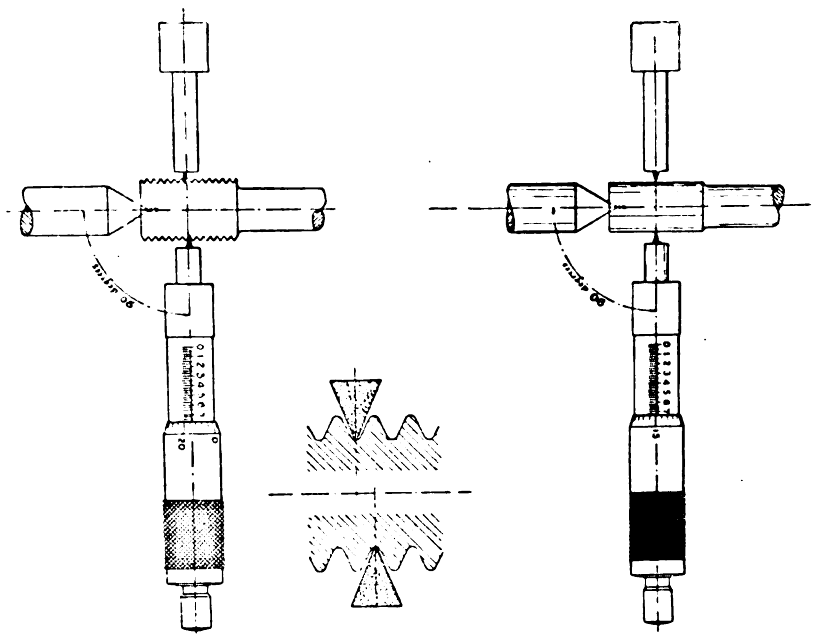

FIG. 35

observed by means of a micrometer, and the difference between the two measurements gives the difference between the known size of the standard cylinder and the core diameter of the screw, which is thus determined.

The effective diameter can be measured in a similar manner, using small cylinders or needles bearing on the flanks of the threads instead of vee-pieces bearing at the roots. If p be the pitch, α the angle of thread, d the diameter of the needles, and T the distance between them when they are in place in the screw thread, as ascertained from the difference between the micrometer readings in this condition and when the screw is replaced by a standard plain cylinder, then the value of the effective diameter is given by the formula :—

$$E = T + \tfrac{1}{2}\, p \cot \tfrac{\alpha}{2} - d \left(\operatorname{cosec} \tfrac{\alpha}{2} - 1\right)$$

This formula takes no account of the effect of the rake of the thread. In the case of coarse screws, where the rake is considerable, a small additional term has to be brought in. But for screws of ordinary proportions this correction is negligible.

The size of needle used should be such as to bear on the flanks at or about half the depth of the thread. Thus there is a special size of needle, known as the "best" size needle, which should be used for each pitch and thread form. The mean size of any particular pair of needles being carefully determined the constant

$$P = \tfrac{1}{2}\, p \cot \tfrac{\alpha}{2} - d \left(\operatorname{cosec} \tfrac{\alpha}{2} - 1\right)$$

can then be determined once and for all for that pair of needles, and the formula for the effective diameter measurement becomes simply :—

$$E = T + P.$$

If needles of other than "best" size are used, then the measurement of the effective diameter may be falsified by the effects of errors in angle, unless the constant P is specially calculated in each case for the angle of the thread, instead of for the nominal angle.

Alternatively it is possible, using pairs of needles of various sizes in turn, to obtain a measure of the error in angle. For the measurement by means of needles, though it corresponds to practical requirements, does not agree strictly with the definition of effective diameter, as I gave it to you just now, but relates rather to the relative thickness of the threads. And a thread with a small angle is relatively thicker near the crests than near the roots, and vice-versa. An improved definition of effective diameter, which would apply equally to a defective screw as to a theoretically perfect one, is much to be desired, but not easy to formulate satisfactorily.

You will notice that the co-efficient of d in the formula is $(\operatorname{cosec} \tfrac{\alpha}{2} - 1)$, which for screws of ordinary types is a figure slightly greater than 1. The mistake is sometimes made of trying to simplify the work by making a direct measurement of the distance *over* the needles, when in place in the screw thread, instead of that *under* them as obtained from a check reading over a standard cylinder. In such case an additional $2d$ has to be subtracted from the observed measurement, in order to obtain the effective diameter. The co-efficient of d thus becomes $-(\operatorname{cosec} \tfrac{\alpha}{2} + 1)$ or rather greater than 3, instead of just over 1. Any error in the value taken for the mean diameter of the needles is thus liable to introduce an error of three times, instead of only once, its own amount, in the finally determined value of the effective diameter. This is a consideration of importance when there is likely to be any doubt as to the size of the needles comparable with the accuracy desired in the final result. It would also be important in the case I mentioned where some of the needles were found to be trilobed in section. Moreover, it is necessary in any case to make a check setting of the micrometer on a plain cylinder, in order to get an accurate value of the measurement whether under or over the needles, and in the latter case the check setting is made under conditions less comparable with those of the actual measurement on the screw, so that there is a greater risk of error in the comparison.

It is necessary to constrain the micrometer in some way so as to ensure the measurement being made perpendicular to the axis of the screw. Fig. 36 shews the machine used for this purpose. The screw to be measured is held on centres, supported from the base of the machine. The micrometer is mounted on a small carriage, which runs on balls in two vee-tracks formed on the upper side of an intermediate slide, which is capable of movement, with a certain amount of friction, in a direction parallel to the axis of the screw. The micrometer can, therefore, readily be brought opposite to any part of the screw where

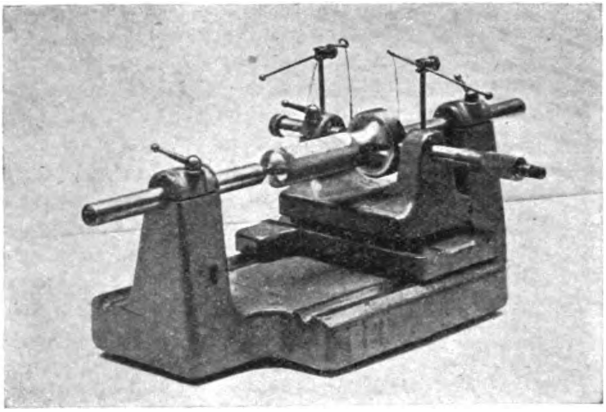

FIG. 36

it is desired to make a measurement, and while held in a plane perpendicular to the axis of the screw is free to pull itself into contact with the two vee-pieces or needles. The latter are suspended by threads from two adjustable hooks. When the measurement is being made they are lightly nipped by the micrometer, and the tension in the threads should then be relieved by lifting them slightly so that they may be free to take up their natural position in the threads.

Whether measuring core or effective diameters contact is made at a single point, on an object of very small radius of curvature, so that great care must be taken to avoid undue pressure. During the war no difficulty was experienced from this cause when using the simple form of apparatus just described. The observers concerned were continuously employed in testing hundreds of gauges every week, and it was found that new observers, previously unacquainted with the work, within a few weeks acquired a fairly uniform sense of touch, so that any observer would give the same result within 0.0001 inch. Since the war, however, with much less work to handle, so that long periods may elapse without practice, it has been found that even the best observers are liable to vary much more in the degree of pressure exerted, and this, particularly in the case of very small screws, has made it necessary to attach a form of indicator to the movable anvil, by which the observer can see when the micrometer setting is correctly made, under a certain definite but very light pressure. This has appreciably improved the concordance of the results obtained.

I must now pass on to the measurement of pitch. Many different types of machine have been devised for this purpose. A very satisfactory one for routine work is that shown in Fig. 37, which was designed by

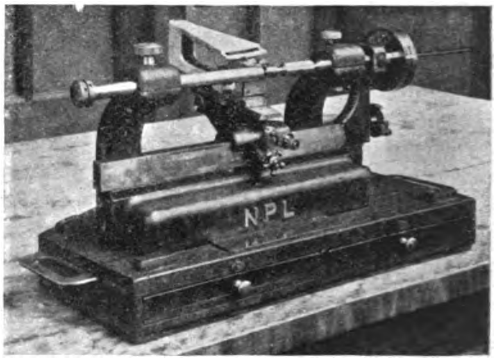

FIG. 37

Mr. E. M. Eden, at the National Physical Laboratory, during the late war. The gauge to be measured is mounted on centres and the indicating mechanism is attached to an L-shaped bar, the longer horizontal leg of which rests on balls in a pair of vee-grooves cut in its under side and on the base of the machine, while in the shorter vertical leg a micrometer is fixed which, pressing against the solid arm which carries the gauge centre, serves to traverse the bar, with the indicator attached, in a direction parallel to the axis of the screw. The indicator consists of a ball pointed stylus held in a block of metal supported partly on a broad flat strip of spring steel in a vertical plane parallel to the axis of the screw, and partly on a double-pointed vertical steel strut, placed a short distance behind the steel strip. The whole mechanism is slightly tilted so that the stylus point bears on the flanks of the threads under a

pressure due to the weight of the parts. The steel strip and strut mechanism enables the stylus, as it is traversed along the length of the screw, to ride freely in and out of the threads, and also, when engaged in any given thread, to rotate slightly about the neutral axis of the strip. At the back of the block which holds the stylus a lever is attached which at its far end actuates a small crank axle mounted in jewelled bearings, to which a very light index finger is fixed. In operation the micrometer screw is turned by means of the divided wheel, and during the rotation of the stylus lever, while the stylus point is at rest in one of the grooves of the thread, a point is reached where the index finger comes to the centre of its travel, and the reading of the divided wheel is then taken. The differences between successive readings, allowing for the known errors, if any, of the micrometer screw, give the measure of the pitch of the screw under examination.

To obviate the necessity of continual arithmetical work, a fully divided wheel is not ordinarily used, but a series of detachable discs are provided, each divided into a comparatively small number of equal spaces. For example, if the screw to be tested has 14 threads per inch, a disc with only seven divisions is used. The micrometer screw, according to type, may have either 40 or 20 threads per inch. Let us take the latter. Thus a pitch of 1/14th inch= 1/20th inch × 20/14=1 3/7th revolutions of the micrometer wheel. So that, if we start on one line of the disc, and the pitch under measurement is correct, the next indication will be exactly on one of the other dividing lines on the disc. There is no need to identify these lines, as they are spaced at intervals much greater than any error that is likely to be present. All that is necessary is to observe the position of the nearest line, at each successive indication, against a short scale graduated on either side of the fixed index mark, by means of which the errors of the successive threads may be read off directly.

For measuring the pitches of internal screws an additional fitting is provided which enables the indicator mechanism to be operated from a small stylus point fixed at the end of a subsidiary lever pivoted on a second vertical steel strip placed with its plane at right angles to the first in such a manner that the stylus can pass right into the ring screw, which is held in a chuck, or on a face plate, instead of between the centres. The accuracy obtainable with this apparatus on either plug or ring screws is about one-ten-thousandth of an inch.

The next illustration (Fig. 38) is of a machine intended to measure screws of greater length, *e.g.*, trial screws from precision screw cutting lathes—to a higher degree of accuracy than is possible with those just described. It is capable of measuring a screw up to 12″ long by 3″ diameter, with a precision approaching 0.00001 inch. The screw to be examined is mounted on centres, and the indicators, of which there are two, recording measurements along two lines on opposite sides of the screw, are traversed past it, as before. To achieve this they are mounted, with suitable adjustments for position, on a long L-shaped girder, running on balls in vee-grooves along the bed of the machine. The short leg of the L is turned upwards, and mounted on gimbals in it is the nut on the master screw, which is arranged in the continuation of the axis of the screw under measurement, so that any error due to imperfection in the ways is minimized. The nut is controlled by an arm, at the end of which is a small roller, which runs along a formed correcting bar, so shaped that the slight rotations which the nut receives as it passes along the screw are sufficient to compensate for any small errors of pitch which may be left in the latter. The nut floats in the gimbals, its weight being taken by plain bushes at its two ends which bear on the full diameter of the screw. The thread is of square form, and is cleared in such a way that the nut makes contact only on one face, which is square to the axis of the thread, thus eliminating any error due to bending of the screw. The abutment of the screw is in the form of a half sphere, the flat face of which presses against a fixed facing on the bed of the machine, while the spherical portion is free to take up its position in a seating in the end of the screw. In this way periodic error is avoided.

The indicators consist of two steel barrels, cut away and mounted by means of crossed steel springs so as to rotate without friction about their axes, on cradles which in turn are suspended by pairs of parallel spring strips, in such a manner that they are free to move in and out, perpendicular to the axis of the screw, but not longitudinally. A small stylus point, of size suitable to the screw to be measured, is fixed in the front

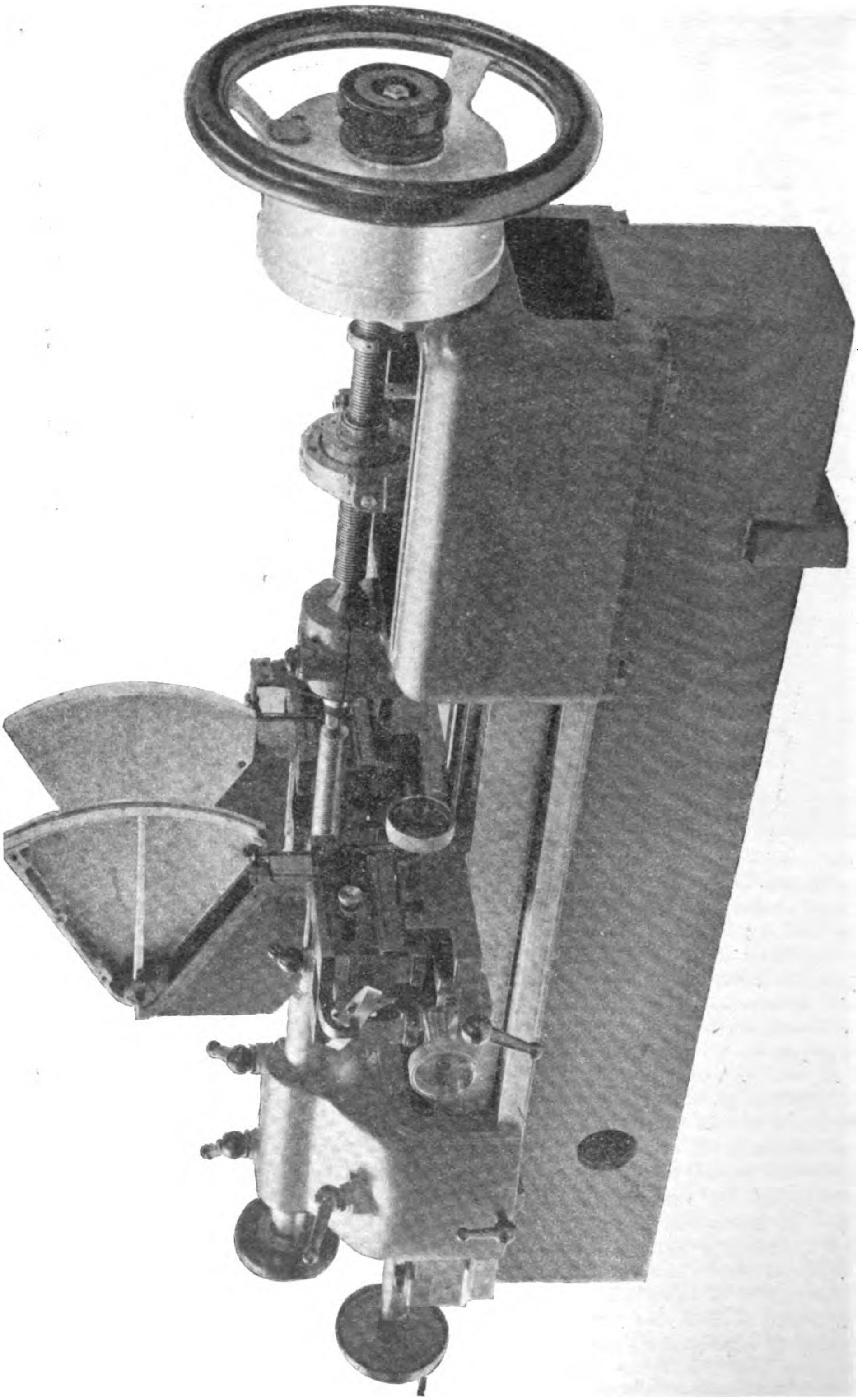

FIG. 38

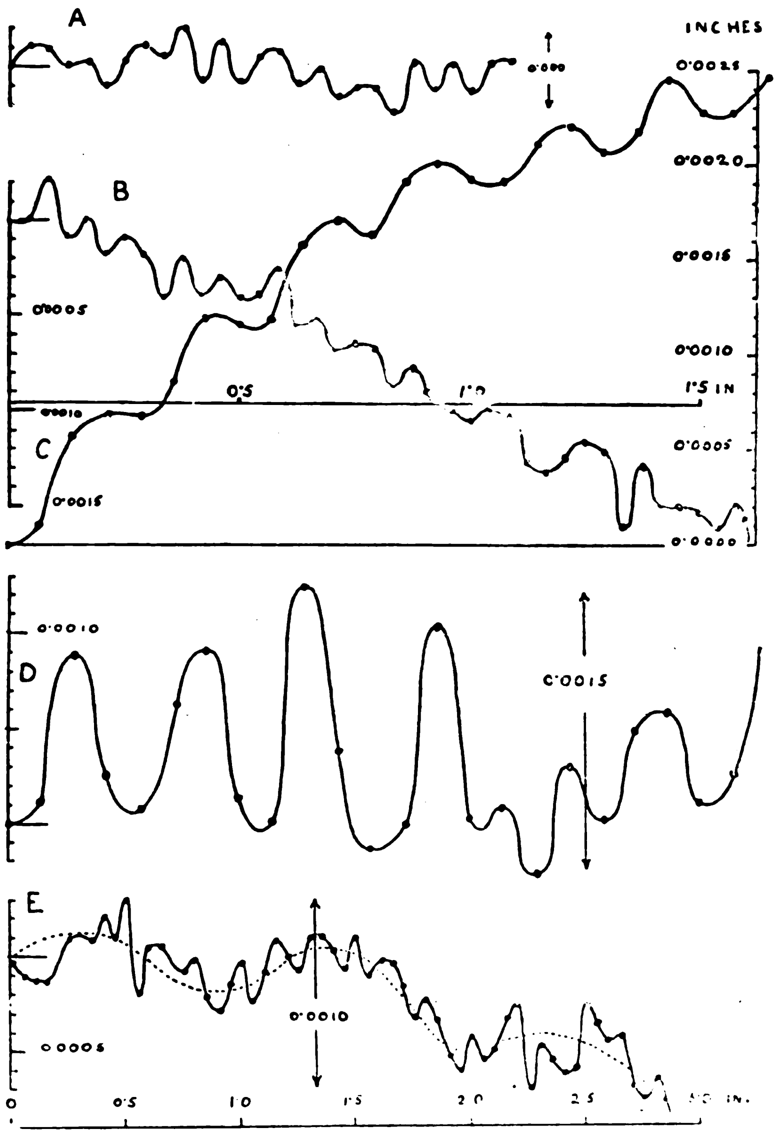

FIG. 39

face of the barrel, at a point slightly above its centre of rotation, and a small horizontal cross bar fixed to the barrel communicates the rotational movements of the latter through a link and lever system to a pointer moving over a scale. The magnification is 1,000 to 1, so that a movement of 0.01 inch at the end of the pointer corresponds to 0.00001 inch error in pitch. The action generally is similar to that of the simple machine just described, the stylus point riding in and out of the threads as the indicators are traversed past, and rocking the barrel over, so operating the indicator mechanism, when engaged with both flanks of the thread in each successive groove.

At the end of the master screw, inside the large drum, are fixed a series of ratchet wheels, with teeth corresponding to the divisions of the discs in the simpler machines. An arrangement is provided by which a pawl can be made to engage at will in the teeth of any desired ratchet, and in this way it is possible to bring the nut rapidly and definitely into a succession of positions corresponding to exact true multiples of the nominal pitch of the screw under examination and thus to read off the errors

along its two sides simultaneously direct from the two indicators. Attachments for measuring the pitches of ring screws are also provided.

As illustrating the sort of errors which are not uncommonly met with in supposedly good screws the following diagrams representing some actual measurements (Fig. 39) may be of interest. In this figure the curve A represents a fairly good, but not very good, screw, having errors not exceeding ± 0.0002 inch. B is a fairly uniform thread, but it is progressively short in pitch by about 0.001 inch per inch. C is long in pitch, rather more than B is short, and at the same time shows a marked "periodic" error, due probably to a defect in the abutment of the leading screw of the lathe on which it was cut. In D the periodic error is very excessive, while in E, a longer screw, a small periodic error is superposed on a longer one which repeats at every inch, and is probably due to a defect or eccentricity of mounting in one or more of the gear wheels in the lathe.

None of these threads could be regarded as at all suitable for a screw gauge, with the possible exception of A, which is on the border line; for in order that a screw and a nut shall assemble together it is necessary that any error of pitch shall be accompanied by an allowance on diameter of approximately twice its amount. The error in the screw marked A in Fig. 39 was ± 0.0002 inch, giving a total error of 0.0004 inches, which would therefore require an allowance of 0.0008 on effective diameter to compensate it, and an allowance of this amount would be in excess of the tolerance ordinarily permitted on screw gauges, except in fairly large sizes.

In a similar way, any error in angle of a screw thread requires some allowance on effective diameter to compensate it. I have explained the method by which the angle of a screw thread may be determined, by using needles of varying size in the diameter measuring machine. This, however, is a slow and laborious proceeding, and it is much preferable to do it by the method of optical projection.

For the purpose of optical examination of screw threads a special type of projector, known as the "vertical" projector, was designed by Mr. Eden, and this not only affords a means of inspecting and measuring the errors of thread form, but is also capable of performing all the measurements of diameter and pitch which can be done by the mechanical machines. For the latter purposes, it is, however, not so generally convenient or simple to operate as they are, and consequently is not usually employed except where a check measurement by an entirely different method is considered desirable.

The idea of this instrument, as compared with the horizontal projector, is firstly to bring the magnified image back into close proximity to the object being measured, so that one operator may have the whole procedure under his own control, and, secondly, to provide a means for actual measurement, which the horizontal projector in its ordinary form does not afford. The screw is placed in a horizontal position, and a parallel beam of light from an arc lamp and condenser on the left is reflected upwards by a prism which is capable of a slight rotation by means of which the light can be directed past the screw in the direction of the rake of its thread. The image is formed by a lens above the screw, and the adjustment of the prism is such that the reflected beam always passes directly into this lens. After passing through the lens, the rays of light, on their way to form the image, are intercepted by an optically worked horizontal mirror placed at some height above the apparatus, and reflected down again so that the image is ultimately formed on a horizontal screen just in front of the screw itself.

Fig. 40 shows the actual apparatus. The screw is mounted on centres on an upper carriage which can be moved, by means of the micrometer on the right, in the direction of its axis. The upper carriage, in turn, rests upon a lower one which can be moved, in a direction perpendicular to the axis of the screw, by either of the two micrometers shown in front. When in the position shown, the left hand micrometer is in operation. By operating the throw-over gear (marked L on the right) the carriage can be traversed freely from back to front, bringing the threads of the screw at the opposite side of its horizontal diametral plane into view, and in this position the right-hand micrometer comes into operation, the thrust of the throw-over weight urging the carriage in the opposite direction. The rake of the thread is, of course, also opposite on the two sides of the screw, so that the direction of the light has to be changed by a move-

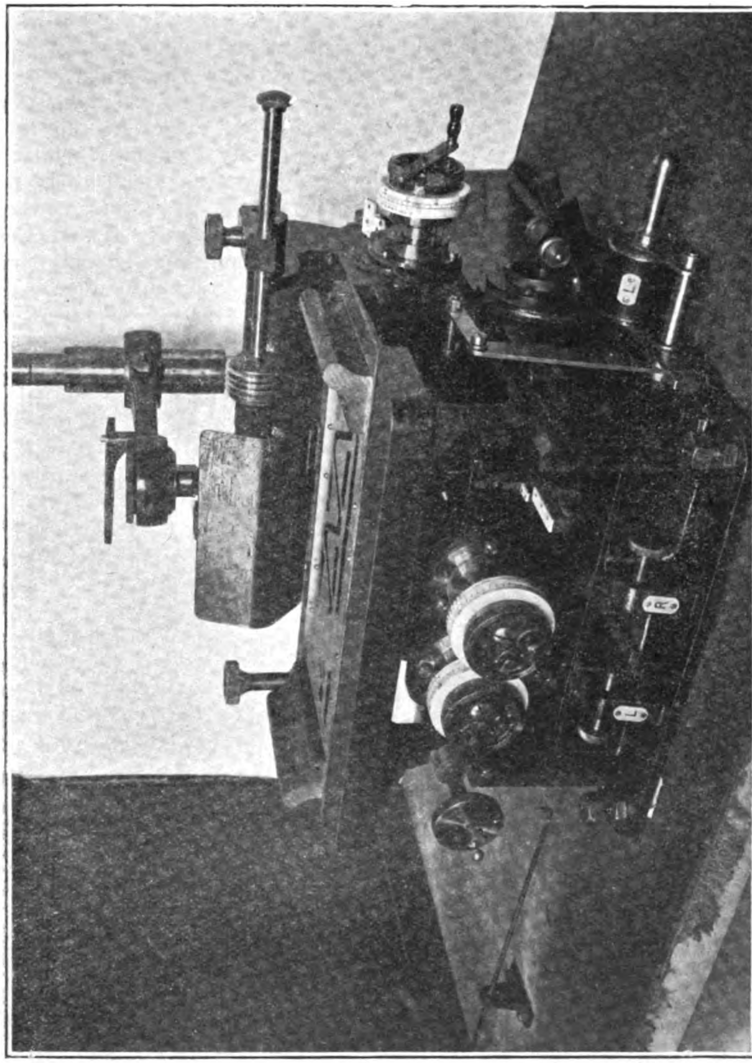

FIG. 40

ment of the lever which sticks out below the two micrometer drums. The correct positions for the rake are easily found by inserting temporarily one or other of the thin lenses carried in a swivelling sector just above the lens. This throws the optical image out of focus, and separates it from the shadowgraph. When the two images are apparently symmetrically disposed in relation to each other the light is correctly directed, and the temporary lens is swung out of the way and the focus restored.

The image is received on a diagram specially prepared to the correct scale (50 to 1 magnification) and the measurements are made by fitting the image to this diagram. To measure pitch the screw is traversed by means of the right hand micrometer, and the successive threads are in turn fitted symmetrically into one of the vees of the diagram, the corresponding micrometer readings being noted. The diagram consists of a dark grey band on a light background, and any overlapping of the image and the diagram appears black, while, of course, any gap appears bright. The fitting can thus be effected with considerable accuracy. The band is of the same width, measured perpendicularly to the axis of the screw, at all points, and two straight bands of the same width are also provided. One of these diagrams may be seen in place on the apparatus in Fig. 40. To make a measurement of diameter a plain

cylinder of known size, approximately equal to that of the screw, is first placed on the centres, and the readings of the two front micrometers corresponding to its two sides are noted, the setting being made to the straight band on the diagram. The screw is then inserted in place of the plain cylinder and the readings of the micrometers when the image is set to the thread form band are recorded. This setting may be made either at the crests, roots, or on the flanks of the threads, giving measurement of full, core, or effective diameter, respectively. The plain cylinder is used for the purpose of eliminating errors in the micrometers themselves, by reducing their function to one of measuring small differences only, and not the whole diameter of the screw.

For the measurement of angle the diagram is replaced by the "shadow protractor"

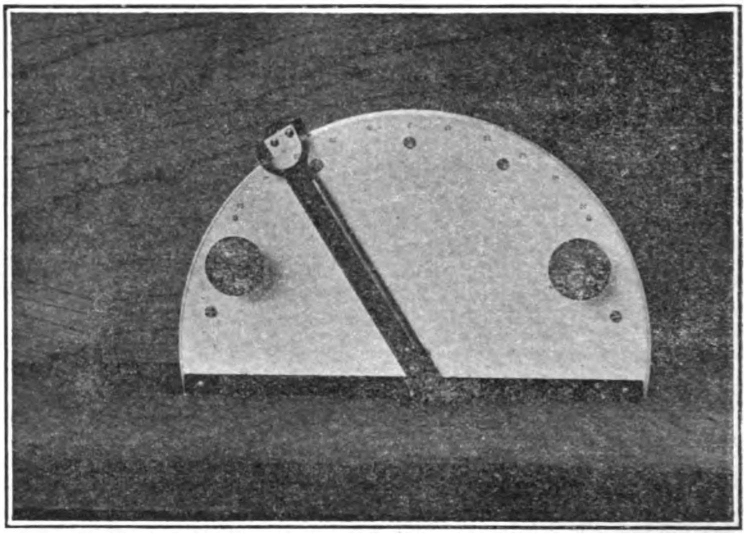

Fig. 41

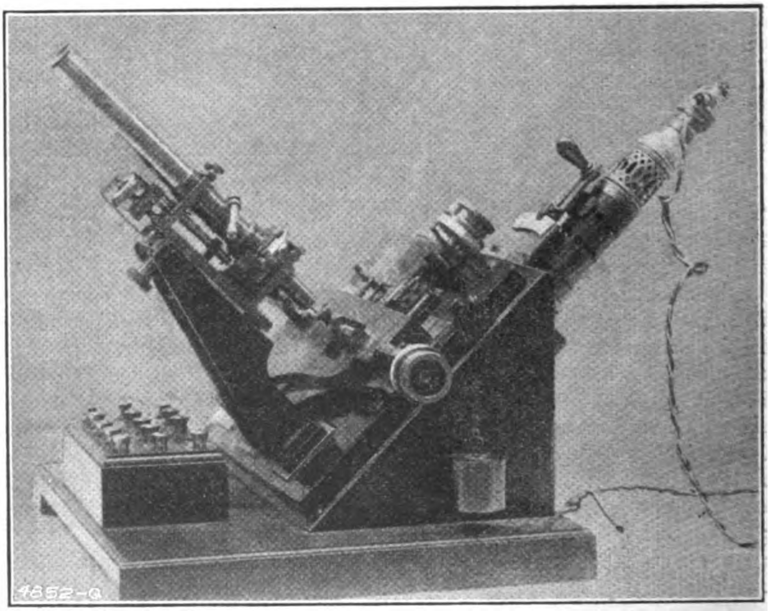

Fig. 42

shown in Fig. 41. The radius arm, and the straight upper edge, of this are slightly raised above the white background on which the image of the screw is focussed. The beam of light from the projector throws keen shadows of their edges on to the background, against which the image is compared. The protractor is first of all set so that the crests of the threads all touch the shadow of the straight upper edge uniformly. The arm is then swung round until its shadow coincides with the flank of the thread in the image, and the angle is read off round the divided circle. The same is done on both flanks in turn, and in this way not only is the total angle of the thread determined, but also its squareness with the axis of the screw. The method is both quicker and more certain than that of mechanical measurement by needles of different diameters.

The next illustration (Fig. 42) is of a machine made some years ago by the Cambridge Scientific Instrument Company to the order of the British Association Small Screw Threads Committee for the purpose of measuring very small screws. In all essential principles it is almost identical with the vertical projector, except that the image is viewed by means of a microscope instead of being projected on to a screen. The screw can be moved across the field of view, either parallel or perpendicularly to its own axis, by means of the two micrometers shown, and angles can be measured by means of a small divided circle attached to the microscope, which rotates bodily in its holder. This machine was used, prior to the introduction of the projection apparatus, for actual measurement of the shapes of small profile gauges such as the driving band gauges which I mentioned earlier in the evening, using the two micrometer motions to measure the positions of various points on the profile in Cartesian co-ordinates. You will readily appreciate that the opera- was a long and difficult one which could not be applied in testing gauges in quantities.

I must now direct your attention to a new problem—the measurement of internal diameters. I described earlier in the evening two methods of measuring the inside diameters of plain ring gauges, both of which may be regarded as somewhat rough and ready, though the method with Johansson gauges and loose cylinders gives fairly good results. By neither method, however, can the highest accuracy be obtained, and by neither method, obviously, can a ring screw be measured. The difficulty of measuring the internal effective diameter of ring screws was for a long time very great, but curiously enough the study of this problem eventually led to the development of two distinct methods, and two distinct pieces of apparatus, each capable of measuring the internal diameters of ring screws with a precision higher than that ordinarily obtained in the comparatively simple operation of measuring plug screws, and at the same time led to a considerable improvement in the accuracy to which the diameters of plain cylindrical rings can be measured.

The first of these new machines was invented by my colleague, Mr. G. A. Tomlinson, and is shown in Fig. 43. A light lever, shown in the centre of the machine, is balanced on two ball feet which rest freely on the horizontal upper surface of a pack

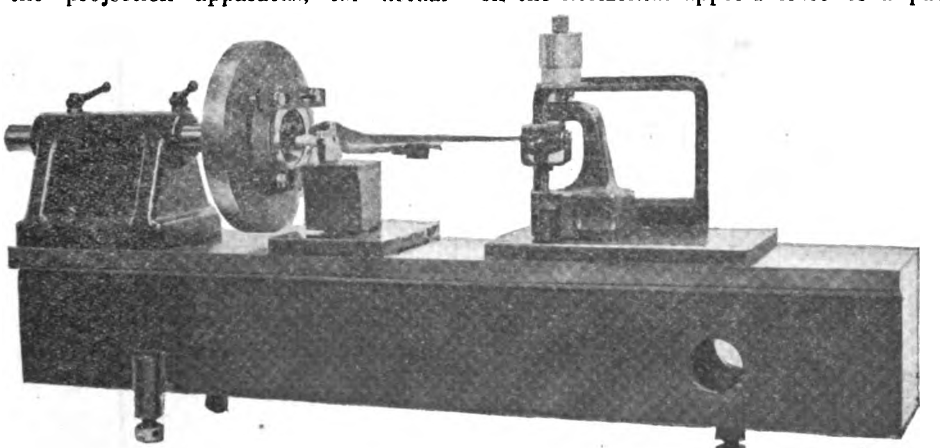

Fig. 43

of Johansson gauges wrung on to the top surface of a cast-iron platform. At the left hand end the lever carries a double-ended ball-pointed stylus, fixed at right angles to its length and in the horizontal plane. The diameter of the balls is "best" size for the pitch of the screw to be measured, and the length of the stylus bar is such that it screws easily into the ring, and has then a freedom of movement, in the vertical direction, roughly equal to 1/5th the diameter of the ring. At its right hand end the lever is finished with a knife edge sector with its edge in the plane of the lever, and slightly convex upwards. A micrometer with enlarged thimble opposes this knife edge, and the contact of the knife edge with the face of the micrometer is observed through a magnifying prism against an illuminated screen.

To make a measurement the pile of Johansson gauges is first adjusted until the lever is practically horizontal when weighted by a small counterweight so as to press upwards in the ring, the two ends of the stylus bar being free to find their bearing in the thread of the screw, along a chord. The pack of Johansson gauges is then reduced by a suitable amount, and the observation repeated with the counterweight reversed, so that the stylus bar presses downwards in the ring, finding its bearing along a chord parallel to the first but at a distance from it governed by the

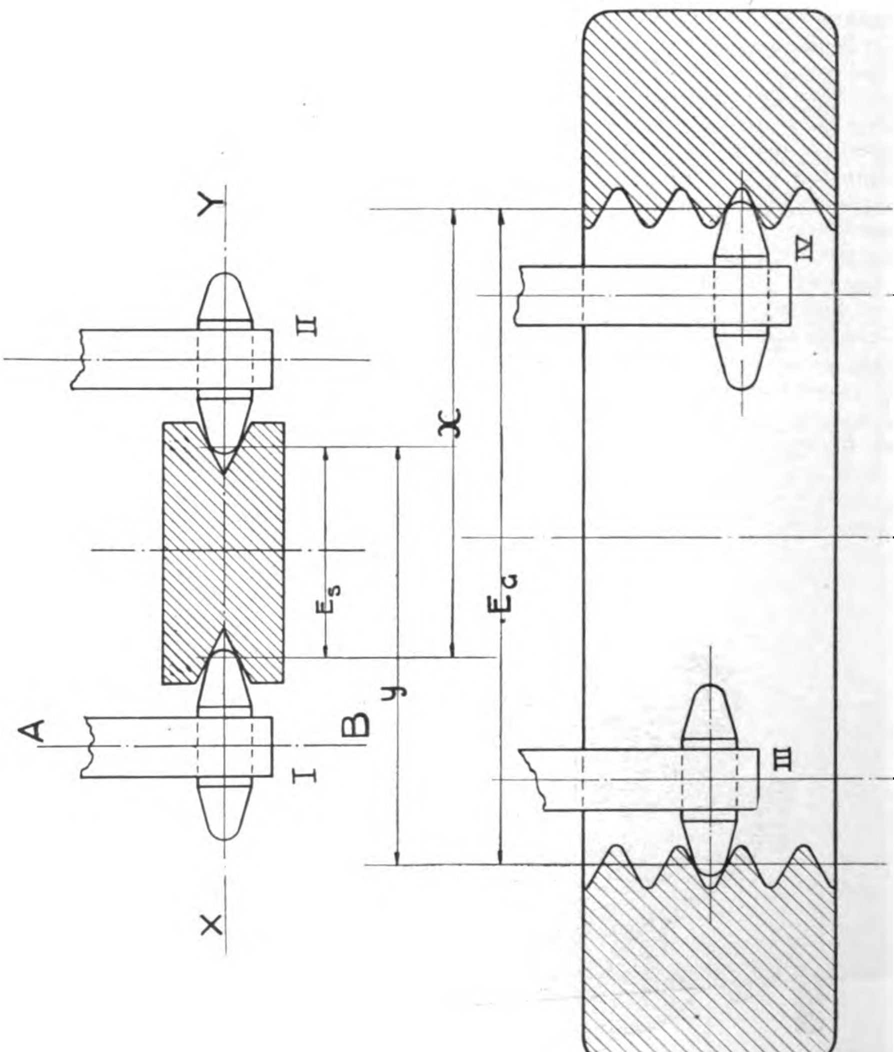

FIG. 44

amount of play between the stylus bar and the ring. The amount by which the pile of gauges is reduced is made equal to that which, by calculation from the known measured length of the stylus bar, would correspond to a ring of correct effective diameter. The difference between the two micrometer readings, less the amount by which the pile of gauges is reduced, is thus a measure of the error in size of the ring. The ratio of length of the two arms of the lever is 5 to 1, so that this amount must be divided by five to get the error in the displacement of the stylus bar, and, if the proportions have been correctly chosen, the factor required to convert this into diameter will also be about 5, so that the initial readings of the micrometer have to be divided by a figure of about 25 in order to obtain the final result. It is easily possible to set the micrometer to 0.0001 inch, and its error should not exceed the same amount, so that the final error in measurement is reduced to about 0.00001 inch provided that the thread in the ring, is sufficiently well finished for measurement to this accuracy to be possible.

The second machine was based on an idea of my own, the design being worked out in the drawing office of the Metrology Department at the N.P.L. It is a more complicated apparatus than Mr. Tomlinson's, though the fundamental idea is very simple. Suppose one has a double-ended stylus as indicated in Fig. 44, which operates some kind of sensitive indicator, and causes this to bear in turn on either side, first of a standard plug of known size, and secondly of the ring it is desired to measure, the latter being placed approximately in the position previously occupied by the former. If we measure the distances x and y, through which the indicator has to be moved between the contacts *made at the same end of the stylus*, we get the simple relation

$$E_g = x + y - E_s$$

relating the effective diameter, E_g of the gauge, and that, E_s, of the standard. The standard can be a simple annular groove, capable of accurate direct measurement, and the accuracy of the result, therefore, depends mainly on the accuracy to which we can measure x and y. The great virtue of the method lies in the fact that in determining these two quantities we take differences of reading between two indications made when the indicator is operating under identical conditions—*e.g.*, the pressure on the stylus point is in the same sense—so that any effect due to backlash or flexibility in the indicator mechanism is eliminated. In most methods of measuring internal diameters the springing of the parts of the apparatus constitutes one of the most serious difficulties.

The actual apparatus is seen from the back in Fig. 45. The ring (or standard) is mounted approximately centrally on a face-plate formed in a vertical plane, on a carriage which can travel on ball and vee-groove guides, in a direction perpendicular to the axis of the ring. The indicator consists of a lever, pivoted on crossed springs about a vertical axis, on a light carriage having a free motion, on ball and

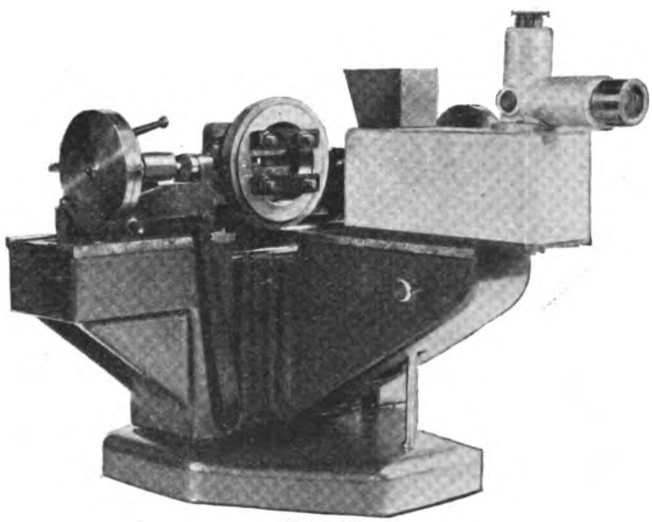

FIG. 45

groove ways, in a direction along the axis of the ring.

The vee-grooves on which the indicator carriage runs are formed in the upper surface of a bracket capable of sliding vertically, under the control of the operator, with a fine adjustment governed by the handwheel in front of the machine. The whole bracket is supported by an inclined tension rod which not only carries the weight but also keeps it in contact with its vertical guides. The far end of the indicator lever works a second small lever, in the same manner as occurs in the small pitch machine, and by a simple arrangement of mirrors and lenses a much magnified image of the motion of a cross-wire on the end of this second lever is brought down to a scale placed just above the indicator casing.

The movements of the main carriage are measured by means of two micrometers, one at each end of the bed, Johansson gauges of suitable sizes being inserted into the gaps between the anvils on the two ends of the carriage and the micrometer faces to take up the major part of the measurement, leaving only small differences to be actually measured by the micrometers, and so eliminating their errors of run. By means of throw-over weights the carriage, and at the same time the indicator pointer, can be made to bear either to left or right, as required. When in use the stylus finds its own way under this pressure into the groove of the thread, pulling the indicator carriage in or out along its guides sufficiently to do so. The vertical motion is necessary, in order to be sure that a diameter, and not a chord, is being measured. The hand-wheel is operated slowly until the image of the cross-wire reaches its maximum excursion, and it is then known that the stylus point is bearing at the end of a diameter. This setting is very easy to make, as a comparatively large error is possible without producing any serious effect on the measurement.

These two machines, differing so essentially in principle, have both been used to measure a number of screw gauges, with wonderfully concordant results—the mean difference between the results being only two or three hundred thousandths of an inch. They can both be used equally for plain cylindrical gauges, and naturally with even greater precision. The measurement of the ring gauge which I mentioned earlier in the evening was obtained in this way, and there is no doubt as to its representing the real size of the gauge, within about one hundred-thousandth of an inch.

Another class of measurement frequently required is that of the distance between lines on a divided scale, photographic record, or other similar object. Two cases which readily occur to the mind are the measurement of star photographs, or spectro-photographs. These may be mounted beneath a microscope on a table with a micrometer traverse—somewhat similar in arrangement to the small screw-measuring machine I showed you, made by the Cambridge Scientific Instrument Company. Or, more conveniently, they may be placed on a fixed table while the microscope itself is moved by a micrometer.

Most instruments of this type, however, suffer from the defect that the line of action of the micrometer screw does not coincide with that of the focal point of the microscope, with the result that any error in the straight-

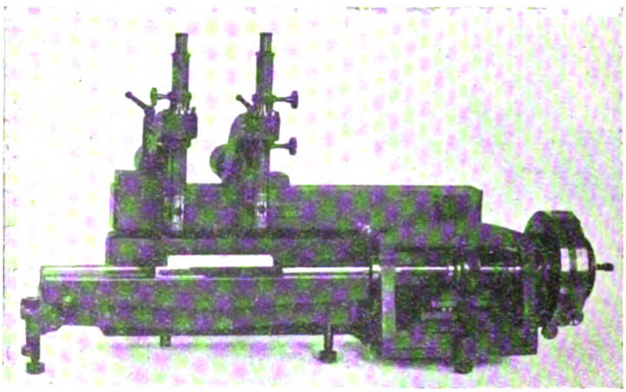

Fig. 46

ness of the guide is reproduced on a proportionate scale in the actual readings of the instrument.

A machine in which this objection is entirely overcome is shown in Fig. 46. This, in common with many others of the machines I have mentioned to-night, was designed and made in the Metrology Department of the N.P.L. You will see that it is an elaborate and expensive piece of apparatus, which it would not be fair to compare with the simple ones ordinarily sold by instrument makers. It has, however, several interesting features, apart from the particular point to which I have referred. Two microscopes can be mounted on the long girder carriage, which runs on a ball and vee-groove track in the direction of its length. An arm attached to this carriage rests by a plane on its under side on a third ball in another groove, and holds the nut, which is operated by the micrometer screw. The axis of the latter is in line with the focal points of the microscopes, so that slight errors of the track are non-effective. The screw is of buttress form, 20 threads per inch, and is cleared everywhere except on the face which is square to its axis, so that errors in measurement cannot be introduced due to bending of the screw. A corrector bar is provided to take up any residual errors in the pitch of the screw.

The measuring head has one other feature of special interest, in that it is capable of giving direct readings equally accurately in either inch or metric units. To attain this object advantage was taken of the fact that one inch equals 25.4 m.m. exact to within one part in a million—a lucky chance, but one dependent upon the understanding that the inch and metric measures are adjusted to be correct at the same temperature, which is a matter of convention, and still the subject of controversy, the orthodox metric school holding that even customary metric measures, as distinct from the scientific standards on which they are based, should be correct at 0° C. and not at the ordinary temperature of use. This line of thought does not, however, correspond with the reasonable requirements of everyday practice since it has the effect that metre lengths of various materials, having different co-efficients of expansion, are no longer equal when brought to ordinary conditions, and in this country, for industrial purposes, it is now the general practice to make Metric and British measures both correct at the average temperature of 62° F.

Reverting to the instrument we were discussing, the screw has 20 threads per inch, and one revolution equals 1/20th inch. One side of the circle fixed to the screw spindle is graduated with 500 divisions each of 1/10,000th inch and reading direct by vernier to 0.00001 inch. The other side of this circle is divided into 635 equal but un-numbered divisions, each one of which is 1/12,700th inch, or 1/500th m.m. Against this circle, it is possible to read by vernier to 1/10,000th m.m. But it is not possible to count the divisions conveniently. To enable this to be done a second circle is made, by means of suitable internal gearing involving the use of a gear-wheel with 127 teeth, to rotate 1.27 times as fast as the circle fixed to the screw. This second circle is divided into 500 divisions, each one of which, therefore, passes a fixed index at the same time as the corresponding graduation of the circle divided to 635. One revolution of this second circle, therefore, represents one millimetre, and the division into 500 equal numbered divisions enables the count to be made, while small errors due to the gearing are eliminated from the final result by taking the vernier reading against the circle which is actually fixed to the micrometer screw. The accuracy of reading, 0.00001 inch, or 0.0001 m.m., which is provided for is considerably above that of the ordinary types of travelling microscope, but in view of the special features of the design there is every reason to hope that it may be actually attainable, though the final adjustment of the corrector bar has not yet been made, and the machine, therefore, has not so far been fully tested.

The travel afforded by the micrometer screw is 6″ and the provision of two microscopes enables scales up to 12″ in length to be measured at one setting. It also enables this instrument to be used after the fashion of a longitudinal comparator, for determining subdivisions of a short scale in terms of its overall length, using the micrometer screw in this case solely for measuring small differences, and not relying on the accuracy of its calibration.

The last instrument I wish to describe is one recently constructed at the N.P.L. for the purpose of measuring the accuracy of form and size of gear wheels. The design of this machine was due to Mr. G. A. Tomlinson, and it is capable of performing several

different operations which renders it somewhat complicated in appearance, though not essentially so in principle. You are all, no doubt, familiar with the fact that certain gears are noisy and inefficient, and others silent and efficient. But probably you hardly realise that these marked differences may be due almost entirely to errors of only a few ten-thousandths of an inch in the shape of the teeth, or in the equality of their spacing. With the application of gearing on such diverse scales as for watches and clocks, motor cars and marine turbine reduction gears, the question of their accurate measurement assumes a very high degree of importance, and a good many attempts have been made to solve the rather complicated problems involved. I venture to think that the machine I am about to describe, which is intended to deal with gear wheels of moderate size, such as those for motor cars or lathes, is the most complete and satisfactory yet produced for the purpose.

A general view of the machine is shown in Fig. 47, where it is set up for the measure-

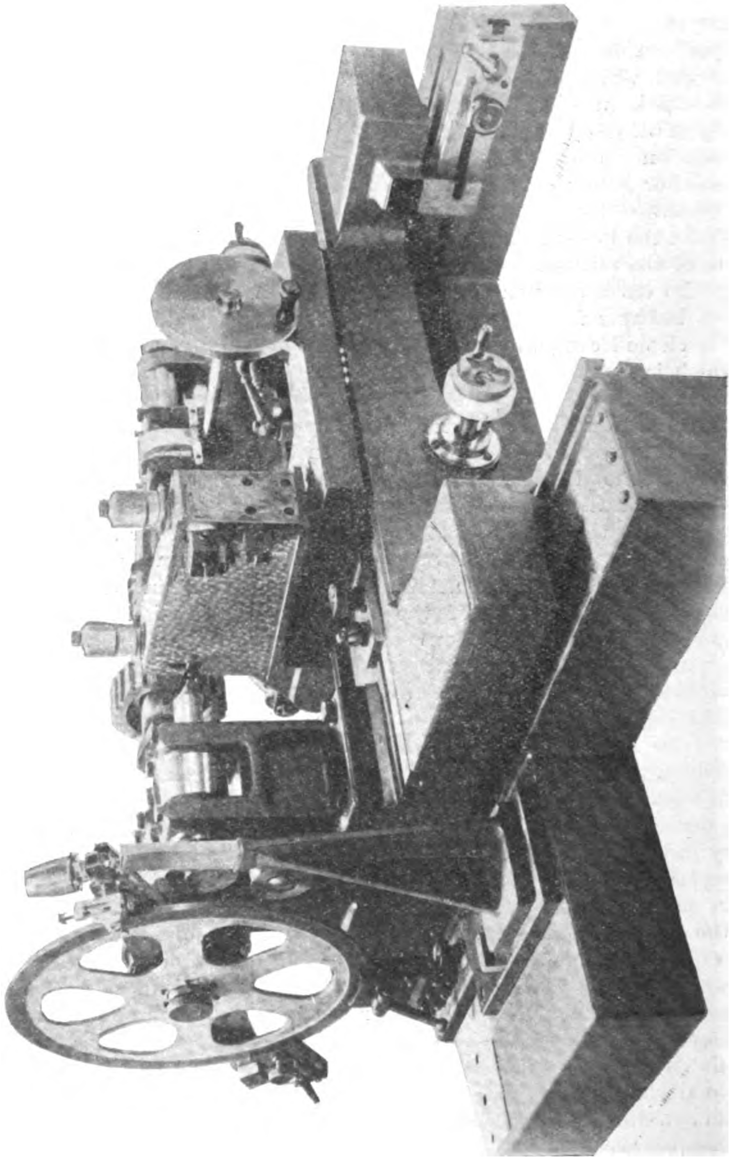

Fig. 47

ment of pitch, or angular spacing, between successive teeth. The wheel to be measured is mounted on a mandrel, between centres, and is attached to the large disc shown on the left, by which it can be rotated. Behind the disc is an independently rotatablo arm, carrying at one end a clutch by which it can be attached to the disc, and at the other a ball-ended stop. A second clutch is provided on the bed plate of the machine, by means of which the disc can be rapidly clamped to the latter.

The arrangement of the indicator is shown in Fig. 48. A stylus point is mounted on a light crossed spring pivot on a block which slides freely in a vertical direction on a ball-and-vee track, being held up into position by the weight of a heavy bell crank lever operating through an inclined strut. The left hand micrometer controls the height of the block. At the other end of the light lever, to which the stylus point is fixed, there is a curved knife edge sector of the same kind as that employed in the chord type of internal diameter measuring machine, and the position of this sector is observed against the face of the right hand micrometer. For ordinary work the left hand micrometer is moved until contact with the right hand (fixed) micrometer is observed, and the reading of the left hand micrometer taken. But for fine work, where only small differences need to be measured, the operation can be reversed. The left hand micrometer is then fixed, and the small differences are recorded by the rotation of the stylus lever about its pivot, as measured by the movement of the right hand micrometer which is necessary to restore contact with the sector. The ratio of the lever is 5 to 1, so that in this way five times the sensitivity of measurement is obtained.

To make a test for pitch, the disc and arm are gripped together and the ball stop is brought into contact with the upper surface of a pack of Johansson gauges wrung on to a flat face on the top of the column on the right of the disc. The stylus point of the indicator is then brought to bear on the face of the corresponding tooth of the wheel and a micrometer reading is taken in the manner just described. The Johansson gauges are then removed, and the ball stop is brought into direct contact with the top of the column. The length of the gauges used is adjusted so that this movement should rotate the wheel through an angle exactly equal to its nominal pitch, and if the indicator be again set,

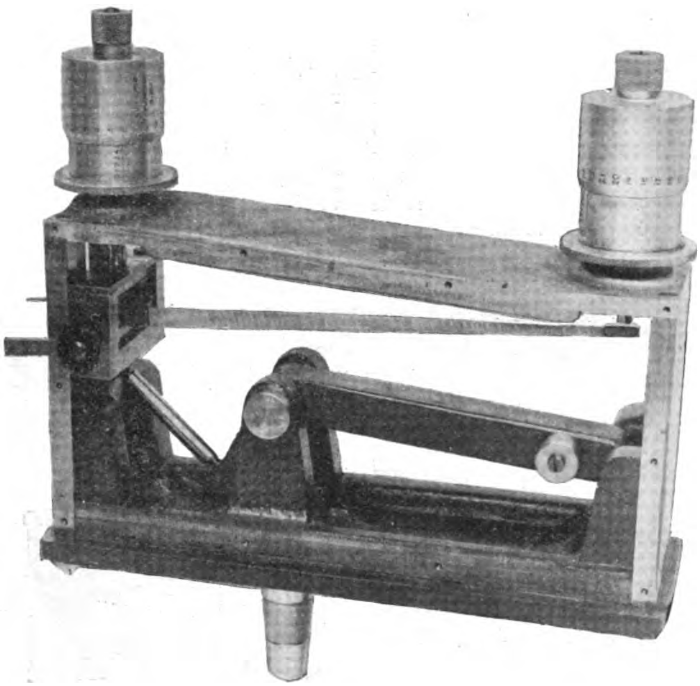

FIG. 48

the micrometer should read the same as before. If it does not, the difference in reading gives the measure of the error in pitch between the two teeth of the wheel concerned. The disc is them clamped to the bed-plate and the arm released and turned back until the gauges can again be inserted. The ball stop is brought down again on to the top of the pack, and the machine is in condition for measuring the pitch of the next pair of teeth.

For measuring the shapes of the teeth, the carriage on which the indicator is mounted is provided with two horizontal micrometer movements at right angles and the indicator itself has a small vertical motion under the control of its own micrometer, so that it is possible to make co-ordinate measurements on three dimensions. A better way of recording the profiles, however, is by means of a special pantograph, which can be substituted for the indicator. This attachment is shown in Fig. 49. The stylus point is passed round on a scale of 1 to 1, by a sharp needle point at the other end of the linkwork, and this needle point traces an exact record of the motion on a small piece of glass, coated with a thin smoke film, which is held against the plate at the back of the fixture. This trace can then be placed in a projection apparatus, and appears on the screen as a fine line diagram, 50 times the size of the original tooth, and capable of measurement to about 0.0001 inch. Special attention has to be given to the very accurate construction of a pantograph for this purpose, as very small errors in the positions of the pivots might introduce distortion into the record sufficient to vitiate measurements of this accuracy. If the same operation be repeated from tooth to tooth, rotating the wheel by means of the large disc through successive equal angles slightly smaller or slightly greater than the true pitch, we get a diagram in which the forms of all the teeth are separately visible and comparable, and in which any errors in

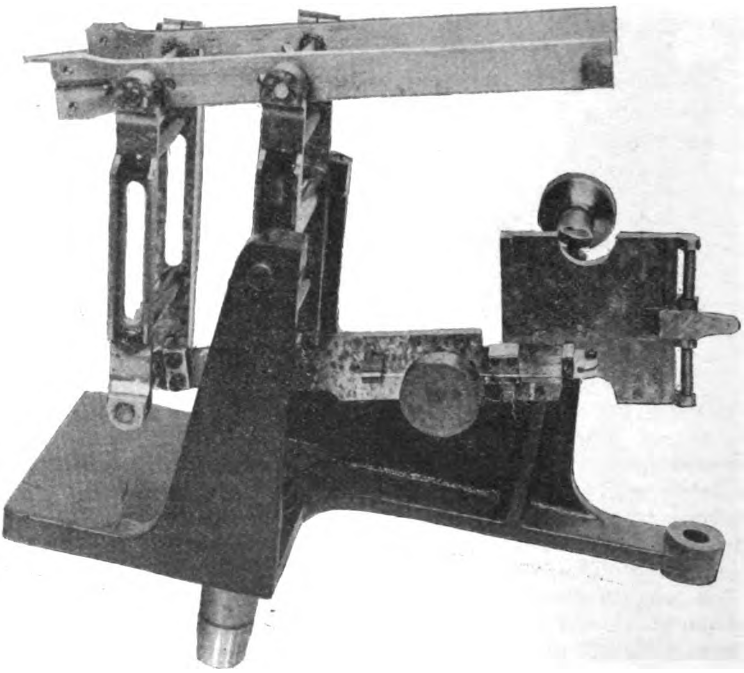

FIG. 49

the surface of the tooth, being carefully kept in contact with it throughout. The whole mechanism is specially balanced so that it will rest freely in any position in which it is set, so as to facilitate this. The motion of the stylus point is reproduced pitch are shown up by differences in spacing.

There is still one more operation of which this machine is capable, and that is, to give an actual record of the uniformity or otherwise of the rotation which one gear wheel transmits to another. To achieve

this the two gear wheels to be tested are mounted on parallel shafts, in mesh. The arm previously mentioned is clamped to the large disc, but a second arm is flexibly connected to the main spindle by three radial spring steel strips, and has a slight freedom of rotation relative to it. Rigidly attached to this second arm and to the second shaft, are two steel discs, whose diameters are in the exact ratio of the numbers of teeth on the two wheels. An endless steel tape passes round these discs, and is kept taut by a weight over a jockey pulley. The two shafts are revolved together by hand, keeping the gears in engagement, and any variation in their relative motion gives rise to a slight rotation of the second arm relative to the first. These slight movements are magnified by a lever system, ending in a needle point near the axis of the large disc, which makes a trace on a smoked glass held in a plane perpendicular to this axis. If the gears are perfect and the diameters of the two steel discs are in the correct ratio, the trace of this needle will be a simple circle. An error in the ratio of the diameters of the discs will cause this to change into a spiral, while any errors in the gears will be shown as irregular movements on either side of this spiral. In this way the nett effect of the combined errors of the two gears on the uniformity of the transmitted motion can be ascertained.

To sum up, I have endeavoured in these lectures to describe to you, firstly, how our ultimate standards of measurement are controlled and maintained ; secondly, how the dimensions of various types and sizes of derived standards may be ascertained in terms of the fundamental standards ; and, lastly, I have described a number of practical applications of these standards and methods, and some of the apparatus used in these applications. If I have been successful in showing that the apparently simple task of " measuring things " is one demanding considerable care and thought if it is to be done properly, and one whose intrinsic interest is greater than might perhaps be anticipated from the mere statement of the problem, I shall feel that I have achieved my object.

[For permission to reproduce the following blocks the author is indebted to the courtesy of those whose names are indicated below :—

Figs. 1, 2, 6, 12, 14, 17, 18, 19, 20, 21, 22, 23, 26 (from the " Dictionary of Applied Physics," Vol. III. : Messrs. Macmillan & Co., Ltd.) ; Figs. 10, 13, 15, 25, 28, 29, 38, 40, 41, 43, 44, 45, 47, 48, 49 (from the " Annual Report of the National Physical Laboratory " : H.M. Stationery Office) ; Figs. 27, 32, 33, 34, 35, 36, 39 (Seventh Hawksley Lecture, by Sir R. T. Glazebrook : The Institution of Mechanical Engineers) ; Figs. 30, 42 (*Engineering*).]

CORRESPONDENCE.

THE SOLUTION OF WORLD PROBLEMS.

It seems to me that any scheme for finding a solution for Europe's troubles is one to which the Royal Society of Arts should give every support for business if not for patriotic reasons. I would, therefore, bring to your notice an American scheme which is capable of still further development in this country than in the States, partly because we are more intimately concerned with the objects it seeks to accomplish ; and I would emphasize the fact that a scheme which has won the approval of two Presidents of the United States (or so it seems) and of most of the prominent business men on the other side of the Atlantic is at least worthy of attention.

It has been realised there that few business men have time to spare in which to evolve schemes which are almost certain to be put in Government waste-paper baskets by officials too proud to consider them. Yet the questions are almost all such as business men alone are qualified to solve. The apathy had to be dispelled by offering some hope of recognition. A reward of £20,000 has been offered for a scheme which is both practical and expedient. A committee of qualified judges has been appointed, and the result is that several men of great eminence have applied themselves to the task.

The prize, however, and the hope of having the scheme put into effect if thought suitable, are only open to Americans ; and it is by no means certain that the scheme adopted in America would prove acceptable to us. Surely some patriotic persons would offer, or contribute towards, a similar prize for a British solution ? At least a committee should be formed to consider schemes, with or without a prize to award to any scheme capable of adoption. Public opinion would put it into effect if generally approved.

Such a scheme would have to provide for :—

(1) Permanent stabilization of currencies.
(2) Obtaining the fullest possible reparations from Germany.
(3) Guarantees for (2) other than Ruhr occupation.
(4) Establishment of an International Court of Justice able to enforce its decisions without recourse to arms, thus attracting U.S.A.
(5) Progress towards permanent peace and prosperity.

D. R. MURRISON SMALL.

NOTES ON BOOKS.

PAINTER AND SPACE, OR THE THIRD DIMENSION IN GRAPHIC ART. By Howard Russell Butler. New York: Charles Scribner's Sons. 21s. net.

How does the graphic artist produce the effect of the third dimension, space? This is the problem which Mr. Butler has set himself to discuss. It is a problem which requires a knowledge both of æsthetics and of physics, and this the author possesses, for he spent several years in the physical laboratory at Princeton, and he subsequently studied art in Paris.

In the most primitive drawings the artist contented himself with a mere outline of his subject; but shading was introduced at a very early stage, and this shows appreciation of the effects of light. The next stage was the introduction of the cast shadow, which at once suggested the rendering of space behind the figure," for the shadow must fall on something, implying the existence of a solid world behind the object portrayed." The evolution of the laws of perspective is traced in a brief but interesting manner; and here attention is drawn to the curious fact that many of the earliest artists who attempted to make practical use of it, reversed the law of perspective and made distant objects larger than those near at hand.

The practising artist will find much to interest him in this volume, especially, perhaps, in the conclusions drawn by the author as a result of his study of binocular perspective. These he summarises thus:—

1. Verticals in planes other than the plane of the focus tend to disappear. They are doubled and their images fall on disparate areas of the retina. For these reasons they lose their force in nature and their importance in the picture may be correspondingly decreased.
2. Horizontals retain their strength better than verticals, but monocular perspective, based on accommodation, tends to blur them to a limited degree.
3. Areas out of focus tend to become unified both as to shade and colour. The overlapped portions exhibit a mixture of tones which makes the areas pass gently one into another.
4. Details and minute objects not in the principle plane lose their importance. An accent, say a black spot on a light ground, if smaller than the overlap, becomes two medium gray spots—accents in this way largely disappear.

The clear manner in which these conclusions are set forth seems to explain very lucidly why realistic painting does not call for distinctness of detail in all parts of a picture. Normal vision is binocular, and that picture is most realistic which represents nature as received by binocular vision.

The author's practical hints, drawn from his own sketching experience, strike us as likely to be very helpful to many painters, who will certainly be interested in the account he gives of the manner in which he made a striking picture of a total eclipse of the sun.

THE CULTIVATION OF SUGAR CANE IN JAVA. By R. A. Quintus. London: Norman Rodger. 12s. net.

Mr. Quintus is the manager of the Krian Sugar Factory in the Sidoardjo delta in Java, and his book originated, as he states in his preface, in planting instructions which he compiled for use on the Krian estate. The work, therefore, has special reference to cultural and local conditions in Java, but it is so thorough and scientific in its treatment that it should realise the author's hope that it may become a manual for his fellow-planters in many other sugar-producing countries of the world.

The volume is divided into two parts, of which the first deals with conditions in Java and the theory of cane cultivation. After discussing points more particularly connected with Java (such as climate, irrigation, leasehold customs, etc.), the author proceeds to deal with the soil (its chemical, physical and bacteriological properties), and various kinds of manure; and this is followed by an admirable account of the sugar cane plant, its morphology, physiology, methods of propagation, varieties, and the diseases to which it is subject.

The second part is devoted to the practice of cane cultivation, and covers the whole ground from classification of soils and methods of tillage to the harvest and transport of the cane, book-keeping, supervision and labour, and cost of production. Some interesting curves are given at the close of the book: from one of these it appears that the total sugar production of Java rose steadily from some 8½ million piculs in 1896 to 29½ million piculs in 1917. After this there was a sharp drop to 21½ million piculs in 1919, but there then followed a rise to 25 million piculs in 1920, the last year given in the diagram.

The book is excellently and copiously illustrated, principally from photographs or sketches prepared by the author.

THE SALT INDUSTRY IN GERMANY.

Rock salt occurs in Germany in two general regions capable of yielding a virtually inexhaustible supply for commerce. The principal region lies in north central Germany in a natural basin, with Stassfurt, famous for its potash mines, as the centre. Another region embraces the so-called Salt Mines Province in Bavaria, forming a continuous geographical and geological unit with the adjacent portion of Austria.

According to a report by the U.S. Assistant Trade Commissioner at Berlin, the salt in the Stassfurt region is obtained mainly by mining. It yields a sodium chloride of 98 to 99 per cent. purity. The concurrent yield of potash salts gives to Stassfurt a special significance as a factor

in Germany's national wealth. Potash mines are worked elsewhere for rock salt in deposits which yield a sodium chloride content of more than 90 per cent. Salt production in Bavaria involves the flooding of the mines and the reduction in salt houses of the brine thus formed. Salt produced by this method is finer and purer than the Stassfurt rock salt.

Salt is produced also in the Magdeburg district. In the vicinity of Schoenebeck salt mines are operated by spraying the mine face to form brine and reducing the brine in neighbouring salt works. The salt works at Schoenebeck, with an annual average production of 60,000 tons, constitute the largest single enterprise of its kind on the continent of Europe. Other important salt works are located at Egestorf, Lueneburg, Stade, Heilbronn am Neckar, and Salzungen.

The marketing of salt for inland consumption is from the mine operators to the trade. For export it is sold exclusively by the Salz-Ausfuhr-Gesellschaft, of Berlin. Although deposits of potash salts occur frequently in rock-salt beds, as is the case in the Stassfurt area, the rock salt is marketed independently of the potash.

The production of salt in Germany in recent years is shown in the following table, the figures in which are from the German Federal statistical office:

Years.	Rock salt.	Brine salt.	Panstone and waste.	Salt by-products.
	Metric tons	*Metric tons*	*Metric tons*	*Metric tons*
1913	1,332,180	678,770	10,710	105,560
1919	1,872,890	298,340	4,960	27,630
1920	2,197,250	341,280	6,680	73,500
1921	1,876,540	317,060	6,920	81,780

The decline in production of brine salt and by-products in post-war years is explained by the shortage of coal for boiling or crystallizing operations in salt works.

The industries producing soda and sodium sulphate are heavy consumers of salt, taking almost as much as is used for food purposes. Other chemical and technical industries, the fodder and fertiliser industry, and the preserving industry also use large quantities of salt.

HIDE AND SKIN INDUSTRY OF UGANDA.

Hides and skins rank as the most important exports from the Protectorate of Uganda. It is estimated that there were at the end of November, 1922, more than a million head of cattle in the Protectorate, although official statistics covering 15 out of 21 districts showed only 687,764 at the end of 1921. Goats are estimated to number 700,000 head and sheep 250,000. Potentially, the Uganda market may be depended upon to furnish 100,000 hides and skins annually, although for the year ending March 31, 1920, on account of the shortage of cargo space during previous years, the exportation reached over three times this figure.

Unfortunately, writes the United States Consul at Nairobi, Uganda hides, in common with those of East Africa, have a reputation for bad curing and for excessive branding on the most valuable parts. As early as 1912 propaganda was directed toward better stretching, cleaning, and shade drying; this is being continued and gradual improvement is anticipated. The control of branding is a matter of great difficulty, since it is essential to the reduction of disease that ownership of animals be readily recognised. Efforts are being made, however, to restrict these brands to such parts as the neck and shoulders. Investigations are now being made to ascertain the serviceability of markings by other means than the hot iron. Chemical agents are being sought which would accomplish this purpose without damaging the skin.

It is estimated that from 60,000 to 70,000 head of cattle may be slaughtered yearly for export in Uganda without depriving the local inhabitants of their annual consumption or decreasing the herds. Recently it was reported that an investigation of the cattle situation of Kenya and Uganda had been made with a view to the establishment of a packing house to make this exportable surplus available. It is thought that a great deal could be accomplished by establishing trade centres with defined stock routes between these centres or buying posts. The costs of production to the native owner are small, and as soon as the great danger of disease is removed, there is no reason why by a proper system of collection such a packing house should not be able to compete favourably with Australian and South American frozen beef.

SOCIAL CONDITIONS IN SPAIN.

An examination of the social conditions of a country forms an indispensable complement to the study of its commerce. In the case of Spain, writes the Commercial Secretary to H.M. Embassy at Madrid in his annual report, they often differ so completely from established conditions in England that fundamental causes must be examined before the differences can be understood. Much that would otherwise be judged by English standards and considered intolerable will then be explained, and the shortcomings in official and business methods be met in a more sympathetic spirit. The necessary practical study requires time and patience, for few countries offer such a variety of contrasts in the psychology and customs of their people as does this peninsula, where the natives of Catalonia, those of the Basque Provinces, the Aragonese, the Galicians and the Andalusians appear almost to belong to different races.

In many respects the Spaniard holds views on life which differ fundamentally from those of the Anglo-Saxon, and his rather philosophic indifference to serious matters may often give rise to a casual way of dealing which, to say the least, is irritating. It is hardly necessary to add that as they are also

a sensitive people nothing is gained by displaying resentment.

Common intercourse in Spain is largely based on exigencies of personal dignity and pride, and so it is advisable for the visitor to maintain a uniform courtesy of manner to all with whom he may come into contact, with little distinction of class. While class distinction exists and makes itself felt, it is not allowed to affect the free and easy intercourse which is so marked in Spain. This spontaneous manner is found to be more in evidence in the interior and in Andalusia than in the capital and the port towns.

A change has, however, taken place, as in recent years large sums have found their way into the country for use in fomenting class hatred. From the rougher and harder nature of the Catalonain and Basque people it can be understood that these provinces have proved somewhat fruitful soil, but in the rest of Spain the easy-going peasant and the patient and somewhat indolent town worker do not aspire to a change, lest a new régime prove but a worse one. Peace and quiet is the keynote of every walk of life.

The fabulous profits of farmers during the war and immediately after had the effect upon the underpaid field workers of teaching them the value of collective action, and many of the larger farmers were forced to agree to contracts on the basis of a fixed price calculated according to prospective profits. Bad times, however, during the past year have brought them back to a standard of wages sufficiently improved to meet the higher cost of living. In many districts the workers are also acquiring small plots of land. Generally speaking the social situation may be described as being satisfactory, considering that during the year 1922 consistent demands were made by employers for reductions of wages.

GENERAL NOTES.

Science and Industry.—It is reported from Geneva, that the League of Nations Commission for International Intellectual Co-operation has formulated a plan by which men of science will be enabled to protect their rights in scientific discoveries. According to a scientific correspondent of the *Observer*, the scheme has been submitted to the Council and Assembly of the League, and in all probability legislation will be recommended to give effect to it. "The average person," writes the correspondent, "has little idea of the extent to which modern industry is indebted to research work carried out entirely without the incentive of pecuniary gain by men of science in their laboratories. With few exceptions, scientists trouble themselves little as to the industrial application of the result of their researches, and their commercial exploitation has been mainly carried out by others, who have enriched themselves by utilising natural forces the existence of which has been demonstrated by others. Particularly is this the case in the sciences of chemistry and electricity." The *Observer's* contributor adds that until details of the plan are available, it is impossible to say how they will affect the discoverers themselves. "If scientists continue to be satisfied with demonstrating, or theoretically proving, the existence of certain natural phenomena, and leave others free to apply them to industrial and commercial purposes, it is difficult to see how they can be protected. But it might be possible to devise a scheme whereby a percentage of the profits accruing from the industrial exploitation of a scientific discovery should be ear-marked for subsidising scientific research work in the country where the discovery was made, and for providing pension funds for professional men of science, who, particularly in this country, are most inadequately remunerated for the important work to which they devote their lives."

Regulation of the Formosa Tea Industry.—With the desire of aiding and encouraging the Formosa tea industry, the Government has embarked on a policy of official regulation. As a first step, writes H.M. Consul at Tamsui, the Government proposes to endeavour to standardise production by encouraging the present small holders to amalgamate their properties, and thus gradually introducing the estate system such as obtains in India and Ceylon. The use of machinery in the different stages of firing is, moreover, to be extended by means of a system of financial subsidies. The second step is the establishment, to be carried out as early as possible during the present season, of an inspection office for all Oolong teas destined for export. The third step is the creation of a central market, where all teas would be sold publicly, thus doing away with the present admittedly uneconomic system under which the tea passes through numerous hands on its way from producer to exporter.

Sericulture Experiments in Venezuela.—Experiments have been carried on for a number of years at Merida, Venezuela, with a view to establishing sericulture there on a commercial basis. Although there have been many setbacks and discouragements, the ultimate result, according to a report by the United States Consul at Maracaibo, is said to be a complete success. A grower who has been very active in conducting these experiments states that he now has a species of silkworm, and a variety of mulberry tree thoroughly adapted to the climatic environment of that section of Venezuela, the altitude of which ranges from 3,000 to 4,000 feet above sea level. Land in this vicinity suitable for mulberry trees is practically unlimited. On this plantation there are about 10,000 trees, over 40,000 producing worms, and 300,000 eggs in storage. The actual production of raw silk with the present strain of worms was begun about a year ago, and this plantation is now prepared to begin producing on a commercial basis.

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICES.

OPENING OF THE 170th SESSION.

The Opening Meeting of the 170th Session will be held on Wednesday, November 7th, when an address will be delivered by LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, on "Exhibitions." The Chair will be taken at 8 p.m.

DOMINIONS AND COLONIES SECTION.

A meeting of the Dominions and Colonies Section Committee was held on Monday, October 15th. Present—Lord Askwith, K.C.B., K.C., D.C.L. (Chairman of the Council) in the Chair, Lord Blyth (Chairman of the Committee), Mr. E. T. Agius, Mr. A. H. Ashbolt (Agent-General for Tasmania), Mr. Byron Brenan, C.M.G., Hon. Sir John A. Cockburn, K.C.M.G., Mr. P. J. Hannon, M.P., Major Sir Humphrey Leggett, D.S.O., R.E., Sir Charles Metcalfe, Bt., Major H. Blake Taylor, C.B.E., and Mr. T. J. Whittington (representing the Agent-General for Queensland), with Mr. G. K. Menzies, M.A. (Secretary of the Society), and Mr. S. Digby, C.I.E. (Secretary of the Dominions and Colonies and Indian Sections).

SCHEME FOR THE IMPROVEMENT OF INDUSTRIAL DESIGNS.

The Royal Society of Arts has for many years endeavoured to encourage the production of good designs for industrial purposes by awarding medals and small prizes to students in Schools of Art. This work was carried on under the Owen Jones Trust, a fund which only provided an annual sum of about £15. In spite of their small value these prizes have been eagerly sought, and the competitions have been so successful that the Council have decided to develop the scheme on a greatly extended scale.

The Society will hold an Annual Competition of Industrial Designs—one class open only to students of Schools of Art, the other open to all. The subjects so far arranged are divided into four sections—Architectural Decoration, Textiles, Furniture, and Book Production—and it is hoped at an early date to appoint Committees to deal with the remaining subjects into which artistic design may be said to enter. After each competition it is proposed to hold exhibitions of selected designs in suitable centres. The Society's Diploma will be conferred on any candidate of outstanding ability. It is hoped that this will soon come to be recognised as a hallmark of excellence, and anyone possessing it will be known to employers as a designer not only of the highest artistic merit, but also with a practical knowledge of the materials and processes of his trade.

In order to add to the attractiveness and utility of the competition, the Society is anxious to raise a fund to establish money prizes and, if possible, one or more travelling scholarships. The young designer of promise is often prevented by lack of means and leisure from acquiring that education which is the basis of the best original work. It is felt that the establishment of such scholarships would be of immense value in creating a class of select designers, and would eventually tend to raise the general level of design throughout the country. This result would certainly exert a healthy influence on our export trade, for there can be no doubt that wealthy buyers throughout the world will come to those markets where the best taste is to be found.

The Council believe that the Scheme will be as useful to manufacturers as to designers. The manufacturer is anxious to find the best designers, and under present conditions he very often does not know in which direction to look for them. The designer will now have the opportunity of proving his skill, with the great advantage of publicity and encouragement, and the exhibitions will be a means of bringing his

work directly under the notice of those who may be anxious to secure his services.

The Sectional Committees already appointed are as follows :—

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The following is the first list of subscriptions to the fund for providing prizes and scholarships :—

First List of Subscriptions to the Fund for Providing Prizes and Scholarships.

	£	s.
Messrs. Tootal Broadhurst Lee Co., Ltd. ..	100	0
Messrs. Waring & Gillow, Ltd.	50	0
Messrs. Simpson & Godlee, Ltd.	25	0
Messrs. Turnbull & Stockdale, Ltd. ..	25	0
Harold Waring, Esq., C.B.E.	25	0
Lord Riddell	20	0
Sir Frank Warner, K.B.E.	20	0
Bookbinding Section, London Chamber of Commerce	15	15

Messrs. John Brown & Son, Ltd.	10	10
Syndics of the Cambridge University Press	10	10
The Carpet Manufacturing Co., Ltd.	10	10
Delegates of the Clarendon Press	10	10
Messrs. John Crossley & Sons, Ltd.	10	10
Messrs. William Heinemann, Ltd.	10	10
John Murray, Esq., C.V.O.	10	10
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Messrs. Fred. Parker & Sons, Ltd.	10	10
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Messrs. John Priestman & Co., Ltd.	10	0
Messrs. John H. Smith & Co., Ltd.	10	0
Messrs. W. H. Smith & Son	10	0
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The Council consider that the foregoing list of donations, a number of which are promised annually, is most encouraging, but they are anxious to see the amount substantially increased, and they appeal with confidence to all who not only are interested in the artistic industries of the country, but hope for the general improvement of British trade to assist them in promoting the Scheme. Contributions to the Fund may be addressed to the Secretary, Royal Society of Arts, John Street, Adelphi, W.C. 2.

REPORT ON THE SOCIETY'S EXAMINATIONS, 1923.

The number of candidates entering for the Society's Examinations has increased steadily since the war. In 1919 the number of papers worked was 31,132; in 1920, it rose to 49,390; in 1921 to 51,267; in 1922 to 56,775; and this year it has broken all previous records by rising to 64,518.

The value of the certificates becomes more and more widely recognised every year. A number of the more important business and industrial firms directly encourage their employees to enter for these examinations, and even grade their junior staffs according to the successes which they obtain. The Council have pleasure in reporting that the Board of Education have recently appointed a representative to serve on the Society's Examinations Committee, a step which may be taken as testifying to the national importance of this branch of the Society's work.

The Examinations were held, as usual, at two periods, March and May. In March the number of entries was 22,362 and in May 45,889. The papers worked were divided between the two Examinations as follows:—

	March.	May.	Total.
Advanced Stage	2,152	6,536	8,688
Intermediate Stage	6,184	16,948	23,132
Elementary Stage	12,952	19,746	32,698

In addition to the 64,518 papers worked in the written examinations, 894 candidates presented themselves for the *viva voce* Examinations in Modern Languages.

The subjects of Examination this year were :—

Arithmetic.
English.
Book-keeping.
Shorthand.
Typewriting.
Economic Geog aphy.
Economic History.
Economic Theory.
Précis-writing.
Commercial Correspondence and Business Knowledge.
Commercial Law.
Company Law.
Accounting.
Banking.
Theory and Practice of Commerce.
Railway Law and Practice.
Railway Economics.
Shipping Law and Practice.
Insurance Law and Practice.
French.
German.
Italian.
Spanish.
Russian.

Arithmetic.—The total number of papers worked in all three stages was 6,568, as compared with 5,560 in 1922. In Stage III. the number of candidates was 253, of whom 35 obtained first-class certificates, 96 obtained second-class certificates, and 122 failed. The proportion of failures is still a good deal higher than it ought to be ; this is due, in the opinion of the Examiner, to great weakness in mensuration and the use of Logarithms, a weakness to which he drew attention in his report last year.

In Stage II. there were 1,522 candidates, of whom 245 obtained first-class certificates, 772 obtained second-class certificates, and 505 failed. In many centres there was evidently no proper preparation for this examination, and candidates showed weakness in such subjects as Banker's Discount and percentages, types of calculations which appear regularly from year to year.

In Stage I, out of 4,793 candidates 3,417 passed and 1,376 failed. It is satisfactory to note that the Examiner reports a general improvement in the style of working and setting out the problems, although in some bad centres the worst faults persist.

English.—In view of the great importance of English as the foundation of education in this country, one notes with pleasure that the total number of papers worked in all three stages is 4,997, as compared with 3,790 in 1922. This is considerably the highest figure on record ; but the general complaint of examiners (to which attention was called more than once in last year's report) that candidates in all subjects and all stages are very deficient in the power of expressing themselves, forces one to the conclusion that the number ought still to grow very largely.

In Stage III. there were 231 candidates, of whom 15 obtained first-class certificates, 112 obtained second-class certificates, and 104 failed. From the papers worked it is obvious that many of the candidates have neither the capacity nor the preparation for such an advanced examination. They frequently show irrelevance and lack of orderly arrangement ; while such elementary faults as bad spelling, bad writing, bad grammar and bad punctuation are far too common even in good papers. Generally speaking, insufficient attention was given to the prescribed books : when a book is set at an examination of this nature, candidates are expected to have a good deal more than a superficial knowledge of it.

In Stage II. there were 1,518 candidates, of whom 93 obtained first-class certificates, 911 obtained second-class certificates, and 514 failed. Although the numbers show an increase over those for 1922, unfortunately there was no corresponding improvement in the quality of the candidates. The Examiner reports that there were more failures and fewer first-classes than usual ; the work rarely rose above the second-rate, while that from certain centres was exceedingly bad.

In Stage I. there were 3,248 candidates (as compared with 2,423 last year) of whom 1,985 passed and 1,263 failed. Here again the increased entry seems to be mainly an increase in weak candidates. Bad grammar, bad spelling, the wrong use of words and phrases, and ignorance of the use of the full-stop are far too common. The percentage of failures in this stage would have been higher but for the excellent work of a few centres. One centre, for example, with over 100 candidates, had only 8 failures, while at another 20 entered and all passed.

Book-keeping.—The figures for book-keeping continue to grow in a remarkable manner. This year there were 20,610 papers worked in all three stages, as against 18,684 in 1922. In Stage III. there were 3,658 candidates; 358 obtained first-class certificates; 1,763 obtained second-class certificates, and 1,537 failed. Only a few candidates possessed a satisfactory knowledge of Income Tax Accounts, while costing was also a weak point with many. Candidates are strongly advised to acquire a knowledge of this important subject from some reliable source.

In Stage II. there were 7,431 candidates, of whom 469 obtained first-class certificates, 4,872 obtained second-class certificates, and 2,090 failed. The Examiner reports that the standard of first-class papers sent in was below the average, although the percentage of passes was higher than last year. Many candidates lost marks through arithmetical errors which prevented them from completing the Trial Balance, while such subjects as Discounts and Returns and Allowances also appeared to be a source of trouble.

In Stage I. there were 9,521 candidates, of whom 4,705 passed and 4,816 failed. There was a regrettable falling off in the work submitted by these candidates, and in view of the large percentage of failures the Examiner drew up a special detailed report which should be carefully studied by both teachers and candidates.

Shorthand.—This subject has for many years ranked next in popularity to Book-keeping in the Society's examinations. The total number of candidates in 1923 was 12,679, as compared with 11,229 in 1922. In Stage III. there were 1,205 candidates; 114 passed the test at 140 words per minute; 566 at 120 words per minute, and 525 failed. In Stage II. of 5,878 candidates, 1,215 passed at 100 words per minute, 2,267 at 80 words per minute, and 2,396 failed. In Stage I. there were 5,596 candidates; 2,350 passed at 60 words per minute; 1,653 passed at 50 words per minute, and 1,593 failed.

The Examiner has repeatedly drawn attention to the confusion often made between £'s, lbs., pence, tons, etc.; he is glad to report that this year's transcripts show a decided improvement in this respect, and, taking the examination as a whole, the standard of work is quite as high as could be reasonably expected.

Those who are interested in the respective merits of the various shorthand systems are referred to the full text of the Examiner's report. It will be seen that pitfalls are to be found in each, although, as a rule, mistakes are attributable to the writers themselves rather than to the particular systems, and would be avoided if the candidates would exercise the smallest modicum of common sense. No system can be responsible for the fault of a candidate who transcribes "Messrs. Price and Porter" as "Messrs. Christ and Water." Among other mistakes quoted by the Examiner are: for "150 bales of Egyptian cotton, balance," "150 bales of cheap cotton blouses"; for "soft goods," "soap cans"; and for "repairs and maintenance," "report and must," and "liabilities and methods."

Typewriting.—The number of entries rose from 5,136 in 1922 to 5,678 this year. In Stage III. there were 587 candidates, of whom 137 obtained first-class certificates, 315 obtained second-class certificates, and 135 failed. The Examiner draws attention to the fact that in the Time Test candidates persist in sacrificing accuracy for speed. "It is preferable to type accurately below the speed required and secure a proportion of the marks instead of at or above the speed inaccurately, and lose all or nearly all marks."

In Stage II. the number of candidates was 2,027, of whom 626 obtained first-class certificates, 1,059 obtained second-class certificates, and 342 failed. The remarks made by the Examiner as to the rendering of the Time Test in Stage III. are also applicable in Stage II. In Stage I. of 3,064 candidates 2,398 passed and 666 failed. While the Examiner reports a decided improvement in the general standard of the work in this stage, he complains of the spelling and arrangement of the answers. The word "celluloid," for instance, was spelt in twenty different ways. One candidate describes an eraser shield as "a cyellerloid fram with a ribber on it," whilst other instances of misspelling were "accross," "fingures," "artical," "orrigganal," and "strate." The plural possessive of "man-servant" and "mistress" was given as "employee's" and "female's"; it was recommended that the signature of a lady writing to and expecting a reply from a stranger should be "Yours affectionately," and "in the case of not knowing whether she is a Miss or a Mrs. she should put 'Ms.' before her name."

Economic Geography.—The entries in this subject, though still far from being as numerous as its importance would justify, show a substantial increase, being 502, as against 285 in 1922. In Stage III. there were 33 candidates, of whom 4 obtained first-class certificates, 15 obtained second-class certificates, and 14 failed. In Stage II. there were 132 candidates; 11 obtained first-class certificates, 84 obtained second-class certificates, and 37 failed. In Stage I. of 337 candidates 215 passed and 122 failed. While the general standard of work and the percentage of passes in Stage I. were at least as high as last year, the Examiner complains that "the papers were badly disfigured by the disgraceful English in which many of them were written. . . . Singular verbs with plural subjects, atrocious punctuation, and lamentable spelling were almost 'normal'; indeed many candidates showed themselves incapable of expressing quite simple ideas in accurate or even sensible language." A large number of candidates lost marks by careless reading of the questions. The same sort of carelessness must be shown by the pupils in doing their school examinations every week or month; and surely a very little trouble on the part of the teachers would teach them to take care to read questions properly. While the Examiner has many points to criticise in the work submitted, it is satisfactory to read his opinion that "the successful candidates are, unquestionably, being very much better taught than they were eight or ten years ago, especially in the matter of mapping. Indeed, this is really the first year that the Examiner has got any pleasure out of the maps, and this applies both to the set map and to rough mapping in the text."

Economic History.—The numbers in this subject, always small, show a slight falling off, being 48 as against 53 last year. In Stage III. there were 11 candidates; 2 obtained first-class certificates; 4 obtained second-class certificates, and 5 failed. In Stage II. of 37 candidates 3 obtained first-class certificates, 19 obtained second-class certificates, and 15 failed. On the whole the work appeared to be of average quality, while some was excellent.

Economic Theory.—The total number of candidates in this subject was 355, as against 259 in 1922. In Stage III. there were 129 candidates, of whom 10 obtained first-class certificates, 80 obtained second-class certificat s, and 39 failed. As is usually the case, a few entered for this examination who should have been advised to attempt a lower Stage, but on the whole the candidates showed a fair general knowledge of the subject, although few reached a really high standard. In Stage II. of 226 candidates 32 obtained first-class certificates, 131 obtained second-class certificates, and 63 failed. A large proportion of these papers were of fair quality.

Précis-writing.—The number of candidates taking this subject shows little alteration, 113 this year as against 114 in 1922. It seems unfortunate that it is not more popular, as it affords an excellent means of training the powers of condensation and judgment of what is essential, what unimportant. In Stage III. there were 50 candidates; 6 obtained first-class certificates, 28 obtained second-class certificates, and 16 failed. In Stage II. of 63 candidates 9 obtained first-class certificates, 37 obtained second-class certificates, and 17 failed.

Commercial Correspondence and Business Knowledge.—The total number of candidates in the three stages was 4,240. In Stage III. there were 96, of whom 12 obtained first-class certificates, 48 second-class certificates, and 36 failed. There is considerable room for improvement in the amount of commercial knowledge displayed, as well as in the correctness with which it is expressed. In Stage II. there were 1,183 candidates, of whom 94 obtained first-class certificates, 907 obtained second-class certificates, and 182 failed. In Stage I. of 2,961 candidates, 1,960 passed and 1,001 failed.

Commercial Law.—581 candidates entered for the two stages of this subject, an increase of 61 as compared with last year's total. In Stage III. there were 249 candidates: 39 obtained first-class certificates, 149 obtained second-class certificates, and 61 failed. The Examiner reports that on the whole these papers, especially those worked in March, gave evidence of a sound and practical knowledge of the subject; the candidates who failed were clearly those who should have entered for the intermediate instead of the advanced examination. The great majority of the candidates appeared to have received careful instruction from their teachers. In Stage II. there were 332 candidates: 96 obtained first-class certificates; 191 obtained second-class certificates, and 45 failed. In this stage

also the candidates appeared to have been well taught, and in most cases to have acquired a sound knowledge of the general legal principles underlying commercial transactions.

Company Law.—There were 415 candidates in the two stages in which this examination is held, as compared with 344 last year. 194 entered for Stage III., of whom 22 obtained first-class certificates, 112 obtained second-class certificates, and 60 failed. The papers generally were not up to the usual standard of proficiency, owing to the fact that many candidates attempted the Advanced paper instead of the Intermediate. Before deciding for which Stage they should enter, candidates ought to make a careful study of the syllabus in order to realise exactly what is required of them. Much disappointment would be avoided if they would take this obvious precaution. As a matter of fact, as the Examiner observes, so far from reading the syllabus some candidates have apparently not even seen its cover: "otherwise a candidate would not refer to the Royal Society of Arts as a trading 'Company' which had dispensed with the word 'limited' by permission of the Board of Trade."

In Stage II. there were 221 candidates, of whom 77 obtained first-class certificates, 133 obtained second-class certificates, and 11 failed. The Examiner speaks very well of the high standard of knowledge, efficiency and ability shown by these candidates: "it is evident that a large majority have benefited by regular attendance at classes, and have taken the fullest advantage of the sound instruction given thereat, which they have wisely supplemented by diligent private study." The small proportion of failures is an exceedingly gratifying feature of this stage.

Accounting.—742 candidates entered for this examination, which is only held in Stage III. 82 obtained first-class certificates, 351 obtained second-class certificates, and 309 failed. While the best papers were excellent, the work, as a whole, was below the average in merit, most candidates showing weakness in Income Tax problems and Costing, both of which are important branches of the subject.

Banking only attracted 37 candidates, as compared with 66 last year. 5 candidates obtained first-class certificates, 16 obtained second-class certificates, and 16 failed. The work submitted was fair, but several candidates showed weakness in practical knowledge of Bank Book-keeping and Negotiable Instruments.

Theory and Practice of Commerce.—768 candidates entered for this subject in all three stages, as against 570 in 1922. In Stage III. of 184 candidates 14 obtained first-class certificates, 90 obtained second-class certificates, and 80 failed. In Stage II. of 445 candidates, 28 obtained first-class certificates, 241 obtained second-class certificates, and 176 failed. In Stage I. there were 139 candidates, of whom 50 passed and 89 failed. At the March examination the percentage of failures reached the very high figure, 92.5. The Council brought this to the attention of the Examinations Committee, who have given the matter the most careful consideration, with the result that an entirely new syllabus has been prepared in all three stages. The subject is a comparatively new one, and many schools have difficulty in finding suitable teachers; but it is earnestly hoped that with the revised syllabus there will be no repetition of such unfortunate results as occurred this year.

Railway Law and Practice.—The number of candidates fell from 207 in 1922, to 107 this year. In quality, however, there seems to have been a satisfactory improvement, especially in English and spelling, on the weakness of which the Examiner commented in his last report. 22 candidates obtained first-class certificates, 54 obtained second-class certificates, and 31 failed.

Railway Economics.—In this subject, as in the last, the numbers are disappointing, the entries being only 35 as compared with 67 in 1922. 4 candidates obtained first-class certificates, 20 obtained second-class certificates, and 11 failed. Unfortunately, the improvement in English and spelling noted in the case of candidates in Railway Law and Practice, does not extend to candidates in Railway Economics.

Shipping Law and Practice.—Of 21 candidates who entered for this subject 3 obtained first-class certificates, 12 obtained second-class certificates, and 6 failed. Having regard to the great size and importance of the shipping industry of the country, it is disappointing that this subject has not attracted a larger number of entries.

Insurance Law and Practice.—Last year, when this subject was first introduced into the Society's syllabus, only 2 candidates presented themselves; this year there were

25, of whom 7 obtained first-class certificates, 17 obtained second-class certificates, and only one failed. The Examiner reports very highly on the general standard of work submitted, and it is earnestly hoped that after this excellent start the number of entries will increase substantially.

MODERN LANGUAGES.

French.—There is a satisfactory increase in the number of entries in this subject, the total being 4,812, as compared with 4,070 in 1922. In Stage III. there were 639 candidates: 83 obtained first-class certificates; 318 obtained second-class certificates, and 238 failed. The work submitted varied very markedly in quality. The Exmainer reports that "among the commercial letters especially there was some brilliant work, several of the candidates scoring 90 per cent. or even more on this part of their paper"; while in free composition some very nearly perfect work was produced. On the other hand, many could not translate into French such simple expressions as "ten years ago," and the Examiner is forced to the conclusion that about a quarter of the candidates enter for Stage III. when they ought still to be preparing for Stage II., or even, in some cases, for Stage I. He considers that it would be far wiser for students who have only obtained a bare 40 per cent. at the Stage II. examination, to spend another year endeavouring to attain a higher standard at that examination, and thus consolidating their elementary work before they go on to the more advanced studies of Stage III. There seems to be no doubt that many candidates do not realise the gulf that is fixed, and rightly fixed, between the Intermediate and the Advanced Stages; and it is earnestly hoped that any who may be in doubt about their own capacities will carefully study the Examiner's Report on Stage III, which should give them some idea of what is expected of candidates in this Examination.

In Stage II. there were 1,652 candidates, of whom 126 obtained first-class certificates, 933 obtained second-class certificates, and 593 failed. The translation was generally better than last year, more attention being paid to accuracy and good English. There is, however, still room for a great deal of improvement in grammar. It is indeed evident, as the Examiner points out, that many candidates are endeavouring to learn French without having first secured that grip of the rudiments of their mother tongue, which is absolutely essential for the thorough and systematic acquirement of any foreign language. Far too many candidates were guilty of such impossible forms as "nous laissent," "nous marcher," "nous achetent," which certainly ought not to appear at this stage.

In Stage I. there were 2,521 candidates, of whom 1,756 passed and 765 failed. It is satisfactory to note that many of the essays were good, and one particularly excellent.

German.—There is a slight increase in the entries for German, the figure being 340, as compared with 276 last year. In Stage III. there were 64 candidates; 20 obtained first-class certificates; 24 obtained second-class certificates, and 20 failed. On the whole the papers were well done, both the translations and the free compositions reaching a high level of excellence. In Stage II. there were 133 candidates; 22 obtained first-class certificates, 79 obtained second-class certificates, and 32 failed. The work submitted here was not so promising as in Stage III., many candidates showing great weakness in knowledge of the rules of syntax. In Stage I., of 143 candidates, 77 passed and 66 failed. The work generally seems to show some improvement on that submitted in 1922.

Italian.—107 candidates entered for this language in all stages, an increase of 14 as compared with the figure of last year. In Stage III. there were 21 candidates; 7 obtained first-class certificates and 14 obtained second-class certificates, there being no failures. In Stage II. of 34 candidates, 10 obtained first-class certificates, 20 obtained second-class certificates, and 4 failed. In Stage I. there were 52 entries; 44 candidates passed and 8 failed.

Spanish.—711 candidates entered in all three stages, as against 676 last year. In Stage III. there were 107, of whom 12 obtained first-class certificates, 77 obtained second-class certificates, and 18 failed. Unfortunately the Examiner still finds it necessary to point out that students cannot expect to obtain a first-class in this stage unless their work is free from grammatical errors. In Stage II. of 289 candidates 27 obtained first-class certificates, 210 obtained second-class certificates, and 52 failed. While the usual weak points still persist (especially lack of grammatical and idiomatic accuracy) the Examiner is able to report

an improvement in free composition. In Stage I. of 315 candidates, 252 passed and 63 failed. Here again improvement in free composition was noticeable.

Russian.—The number of candidates in Russian, which, in 1917, suddenly rose to 266, has steadily fallen with the fortunes of that country, and this year there were only 27 entries in all three stages. 10 candidates entered in Stage III, of whom 2 obtained first-class certificates, 5 obtained second-class certificates, and 3 failed. In Stage II. of 9 candidates, 2 obtained first-class certificates, 7 obtained second-class certificates, and none failed. Here a very good standard of excellence was attained. In Stage I. there were 8 candidates of whom 6 passed and 2 failed.

ORAL EXAMINATIONS.

The results of the Oral Test which is now compulsory for all Candidates in the Advanced Stage of French, German, Spanish and Italian were highly satisfactory. With 30 less candidates there were 50 more distinctions awarded this year, and the number of failures was 88 less than in 1922. An important part of the Oral Test is the taking down of a passage dictated in the foreign language by the Examiner, and in the past this has been a source of great weakness with many candidates. It is gratifying to be able to state that the Examiners now report a very great improvement in this important branch of the examination.

Certificate in Elementary Commercial Knowledge. To gain this special Certificate Candidates must pass in Arithmetic, Book-keeping, English and one other subject within three consecutive years, but it is satisfactory to find that many pupils from the Day Schools mentioned above, pass in the necessary subjects in one year. In view of the fact that a fairly high standard is maintained in the Elementary Stage (it is by no means a first year's examination) the results at Day Schools under the local Education Authorities mentioned, as set forth in the foregoing table, give evidence of really excellent preparation.

Alterations in the Syllabus.

In response to representations from various quarters, three new subjects have been added to the Examination Syllabus for 1924, viz., Foreign Exchange and Stock Exchange Law and Practice (each of these subjects being included in both Stages II. and III.), and Advertising and Salesmanship (in Stage III. only).

The History of Inland Transport was included in the syllabus for 1922 and 1923, but as only one candidate presented himself the subject has been dropped.

Economic History will in future be known as Economic and Social History. Papers will be set in all three Stages in this subject, instead of in Stages II. and III. only, as before.

Oral Examinations held during 1923.

Subject.	No. of Examination Centres.	No. of Examiners	No. of Candidates examined.	Passed with Distinction.	Passed.	Failed.
French	63	41	715	147	441	127
German	12	9	61	17	33	11
Spanish	14	12	96	21	69	6
Italian	5	4	22	12	10	—
	94	66	894	197	553	144

Commercial Knowledge Certificates.

The increase, noted in last year's report, in the number of Candidates entered from Higher Elementary Schools, and also the new Central Day Schools set up under various Education Authorities, has been well maintained. Most of these Candidates take a group of subjects qualifying for the

The entries in Danish and Norwegian, Dutch, Portuguese, and Swedish, for some years have been so small that Examinations in these subjects will be discontinued after 1924, unless there is a considerable increase in the number of entries received.

The Foreign Language Syllabuses have all been revised and also, as previously

	Elementary Stage, 1923.		
	Number of Candidates.	Number of Papers Worked.	Number of Certificates Awarded.
(*a*) MARCH EXAMINATIONS: –			
Chatham, Junior Commercial School	30	88	71
Halifax, Municipal Technical College	45	84	81
Leyton, Capworth Street Girls' School	63	197	175
West Ham, Central Secondary School	30	76	71
L.C.C. Brockley Central School	54	86	70
L.C.C. Brownhill Road Central School	70	96	82
L.C.C. Buckingham Gate Central School	47	50	42
L.C.C. West Square Central School	45	77	66
(*b*) MAY EXAMINATIONS :—			
Ashford (Middlesex), County School	13	55	51
Blackpool, Palatine Central School	36	189	151
Colchester, Hamilton Road Central School	42	56	54
Dartford, County School	15	102	87
Derby, Central Girls' School	18	68	60
Kingston-on-Thames, Day Commercial School ..	127	440	357
Lerwick, Central Public School	15	76	73
Reading, Alfred Sutton Central School	10	49	48
Walthamstow, Queen's Road Central School ..	99	116	104
West Ham, Higher Elementary School, Water Lane	76	142	123
Wood Green, Bounds Green County Girls' School ..	24	64	60
London, "Mary Datchelor" Girls' School	25	67	57
L.C.C. Mina Road Central Girls' School	26	56	49

mentioned, the Syllabuses in all three Stages of Theory and Practice of Commerce.

The thanks of the Council are once more accorded to the Court of the Clothworkers' Company, who have generously renewed their grant of £40, towards providing medals in all the subjects of examination where the work of candidates attains a sufficiently high standard. There is no doubt that these medals are highly valued by those who win them, and they have done much to maintain or raise the level of excellence in the papers worked.

The Examination Syllabus for 1924* has been issued. In it will be found the fullest possible information about the examinations, a syllabus of each stage of each subject, and a list of centres. The papers set in March and May, 1923, have been reprinted in six pamphlets. Each pamphlet contains, in addition to the papers of each stage, the syllabuses of the subjects in the pamphlet and the Examiners' reports on the papers worked. Both teachers and students are strongly advised to study not only the syllabuses, but also the remarks of the various examiners on the results of last year. It will be found that these contain many valuable and helpful suggestions, and the work of the candidates year after year shows that far too little attention is paid to them.

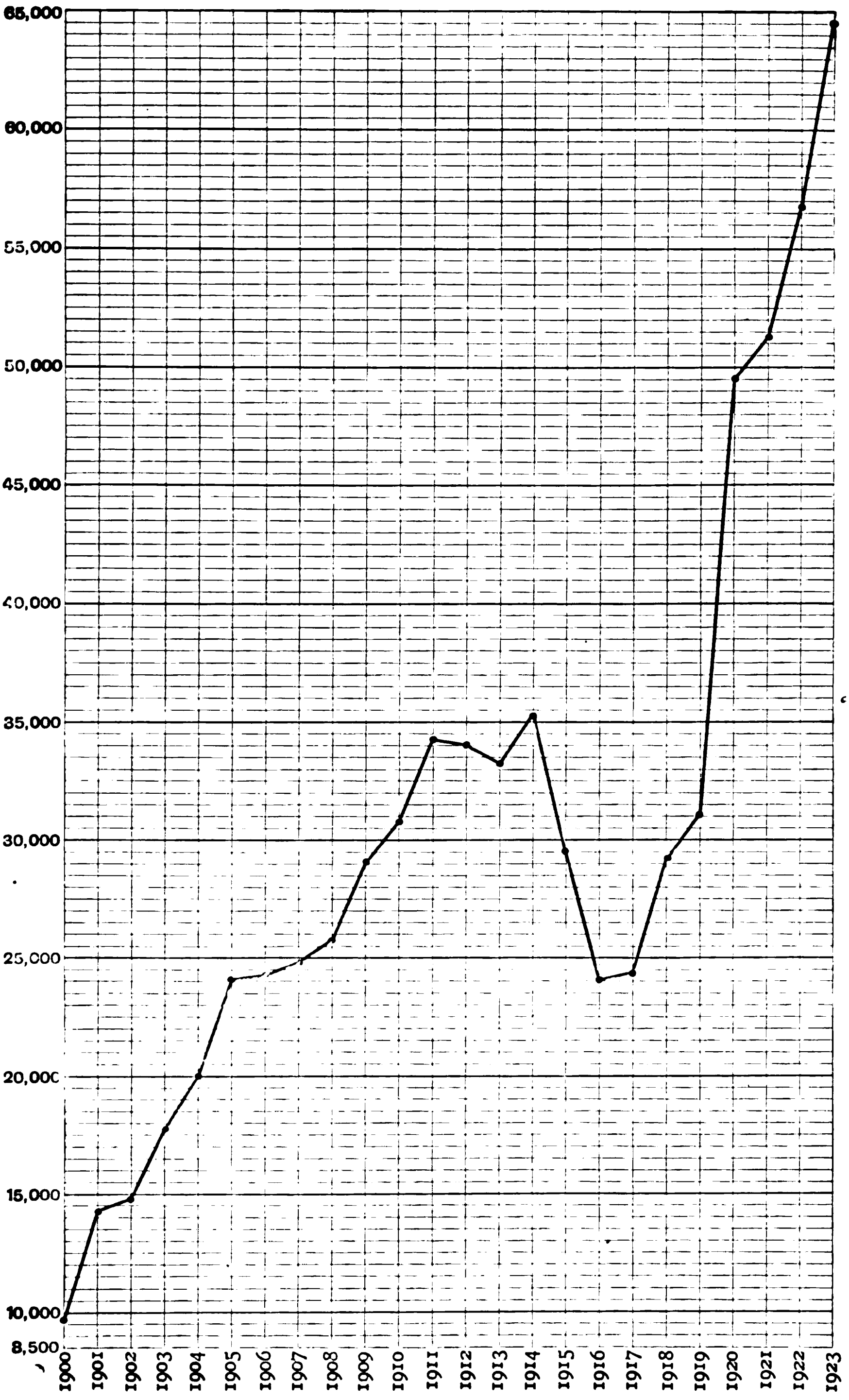
The regulations for the Oral Examinations in Modern Languages are also given at full length in the syllabus.

*The price of the Syllabus for 1924 is 4*d*., post free. Copies can be obtained on application to the Examinations Officer, Royal Society of Arts, Adelphi, London, W.C.(2). The price of the pamphlets containing the 1923 papers is 4*d*. each, post free. Particulars of these may be obtained as above.

Details of the 1923 Examinations.

Subjects.	Stage III.—Advanced.				Stage II.—Intermediate.				Stage I.—Elementary.			Total number of Papers worked in all Stages.	
	Papers worked.	1st-class Certificates.	2nd-class Certificates.	Not passed.	Papers worked.	1st-class Certificates.	2nd-class Certificates.	Not passed.	Papers worked.	Passed.	Not passed.	1923	1922
Arithmetic	253	35	96	122	1,522	245	772	505	4,793	3,417	1,376	6,568	5,560
English	231	15	112	104	1,518	93	911	514	3,248	1,985	1,263	4,997	3,790
Book-keeping	3,658	358	1,763	1,537	7,431	469	4,872	2,090	9,521	4,705	4,816	20,610	18,684
Economic Geography	33	4	15	14	132	11	84	37	337	215	122	502	285
Shorthand	1,205	114	566	525	5,878	1,215	2,267	2,396	5,596	4,003	1,593	12,679	11,229
Typewriting	587	137	315	135	2,027	626	1,059	342	3,064	2,398	666	5,678	5,136
Economic History	11	2	4	5	37	3	19	15	—	—	—	48	53
Economic Theory	129	10	80	39	226	32	131	63	—	—	—	355	259
Précis-writing	50	6	28	16	63	9	37	17	—	—	—	113	114
Commercial Correspondence and Business Knowledge ...	96	12	48	36	1,183	94	907	182	2,961	1,960	1,001	4,240	3,935
Commercial Law	249	39	149	61	332	96	191	45	—	—	—	581	520
Company Law	194	22	112	60	221	77	133	11	—	—	—	415	344
Accounting	742	82	351	309	—	—	—	—	—	—	—	745	745
Banking	37	5	16	16	—	—	—	—	—	—	—	37	66
Theory and Practice of Commerce	184	14	90	80	445	28	241	176	139	50	89	768	570
Railway Law and Practice ...	107	22	54	31	—	—	—	—	—	—	—	107	207
Railway Economics	35	4	20	11	—	—	—	—	—	—	—	35	67
Shipping Law and Practice ...	21	3	12	6	—	—	—	—	—	—	—	21	22
History of Inland Transport...	—	—	—	—	—	—	—	—	—	—	—	—	1
Insurance Law and Practice ...	25	7	17	1	—	—	—	—	—	—	—	25	2
French	639	83	318	238	1,652	126	933	593	2,521	1,756	765	4,812	4,070
German	64	20	24	20	133	22	79	32	143	77	66	340	276
Italian	21	7	14	—	34	10	20	4	52	44	8	107	93
Spanish	107	12	77	18	289	27	210	52	315	252	63	711	676
Russian	10	2	5	3	9	2	7	—	8	6	2	27	43
Dutch	—	—	—	—	—	—	—	—	—	—	—	—	7
Portuguese	—	—	—	—	—	—	—	—	—	—	—	—	13
Swedish	—	—	—	—	—	—	—	—	—	—	—	—	8
Totals, 1923	8,688	1,015	4,286	3,387	23,132	3,185	12,873	7,074	32,698	20,868	11,830	64,518	—
,, 1922	8,423	1,045	4,341	3,037	20,216	3,667	10,739	5,810	28,136	19,133	9,003	—	56,775

DIAGRAM SHOWING NUMBER OF PAPERS WORKED IN THE EXAMINATIONS, 1900-1923.



NOTES ON BOOKS.

LONDINIUM: ARCHITECTURE AND THE CRAFTS. By W. R. Lethaby. London: Duckworth & Co. 12*s.* 6*d.* net.

The origin of London, like that of Mr. Yellowplush, is "wrapt in mystery." There seems to be little doubt that some sort of a town existed here considerably before the advent of the Romans; its name certainly is of Celtic origin—possibly derived, as Camden suggested, from the British word Lhong, meaning a ship, so that London is a Harbour or City of ships. At all events, it seems to have been known from the earliest days of which there are any records, as a centre of sea-borne trade, and Professor Lethaby suggests that it was to Verulam, the capital of the leading Celtic kingdom, "what the Piraeus was to Athens, Ostia to Rome, Dover to Canterbury, and Southampton to Winchester. London was doubtless the source of the wealth of King Cymbeline, and we might very well look on him as its founder."

Interesting, however, as it may be to speculate on the beginnings of the city which has grown to be the largest in the world, this is not the task which Professor Lethaby has attempted in the volume before us. He has set himself the perhaps more profitable labour of painting as clear a picture as is at present possible of the Roman City of London. It is hardly necessary to say that he has done his work with the utmost thoroughness. Thus Chapter I. deals with the building materials and methods of the Romans; he describes, for instance, their mortar and cement and quotes recipes; he deals with their uses of tiles, plaster, and various kinds of tools, and he emphasises the fact that there were very distinctive features in Roman provincial art which differentiated it clearly from the "classical style." Chapter II. is devoted to buildings and streets; Chapter III. to walls, gates and the Roman bridge whose existence has given rise to a good deal of controversy; Chapter IV. to cemeteries and tombs; Chapter V. to some larger monuments, and then follow five exceedingly interesting chapters on sculpture, mosaics, wall paintings and marble linings, lettering and inscriptions, and the crafts.

A careful study of Professor Lethaby's book leaves one with the impression that there must have been much that was beautiful and attractive about Roman London. From the far too little that remains one is able to form some idea of the taste and beauty which must have distinguished many of the buildings. Not only was the architecture admirable, but much of the ornament was full of charm. Professor Lethaby justly grows enthusiastic over Roman inscriptions. "Fine lettering," he writes, "is the most perfect thing in the art of the Romans," and his illustrations justify the statement. The tesselated pavements, which formed so notable a feature of many Roman villas, were often of great beauty, and various crafts for which London became a well-known centre, owed their introduction to this country to the Romans. Among other things, as the late Mr. Harry J. Powell mentioned in his "Glass Making in England," glass was brought to England by them, and the pieces which remain testify to the high standard of skill possessed by our earliest glass-blowers.

It is deplorable that the traces of the Roman occupation have so largely vanished. One would like to believe that the present generation is more sensible than its predecessors of all that antiquity should mean to us. We certainly have active and energetic societies amongst us for the preservation of ancient monuments and buildings, and works like this of Professor Lethaby should do much to encourage an interest in our past. But it is tragic to read of the destruction which has been wrought in comparatively recent times. In 1760 the gates of Aldgate, Cripplegate and Ludgate were sold by public auction in the Council Chamber, Guildhall. Aldgate fetched £157 10s.; Cripplegate £93; and Ludgate, £148.

GENERAL NOTES.

IODINE PRODUCTION IN CHILE.—All nitrate firms in Chile are producers or possible producers of iodine. Anyone of the larger nitrate plants, writes the United States Consul at Iquique, could produce a sufficient quantity of iodine to supply the needs of the entire world, but the Combinacion de Yodo restricts the free production of this drug. At present the limited use of iodine prevents any increase in price being made, and with a view to increasing prices the combination has offered prizes for the discovery of new uses for it. In 1913 the exports of iodine from Chile were valued at 5,134,400 pesos (1 peso = 1s. 6d.), increasing in 1916 to 21,627,936 pesos, representing the largest amount ever exported in a single year. After the war-time demand had been supplied, the value of the export declined, and in 1921 the total export of iodine was 9,991,132 pesos.

DECLINE OF PERSIA'S SILK INDUSTRY.—Persia's formerly flourishing silk industry has been virtually annihilated as a result of the world war, and the collapse of Russia, writes the United States Consul at Teheran. During the fiscal year 1913-14, Persia imported 2,382 batmans (batman = 6.49 pounds) of silkworm eggs, mainly from France, Italy, and Turkey. Such egg imports came via the Caucasian route, which, because of troubled political conditions, cannot be used now, and the long, intensely hot, southern route *via* Bombay and the Persian Gulf ports or Bagdad, has been found impossible, as the length of the journey and the high temperature spoiled the eggs. As a consequence imports of silkworm eggs fell to a negligible quantity (41 batmans) in 1920-21, and Persia's cocoon exports declined from 334,425 batmans in 1913-14 to 146 batmans in 1920-21.

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICE.

NEXT WEEK.

The Opening Meeting of the 170th Session will be held on Wednesday, November 7th, when an address will be delivered by LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, on "Exhibitions." The Chair will be taken at 8 p.m.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

NITRATES AND AMMONIA FROM ATMOSPHERIC NITROGEN.

By E. KILBURN SCOTT, A.M.Inst.C.E., M.I.E.E.

LECTURE I.—*Delivered April 9th*, 1923.

STATISTICAL.

About 45 per cent. of the world's production of fixed inorganic nitrogen is used for fertilisers; about 30 per cent. for making nitric, sulphuric and other acids; and about 25 per cent. for making dye-stuffs, fine chemicals and miscellaneous products requiring nitrogen.

During the war most of the world's output was used for explosives in the form of nitric acid, tri-nitro-toluol, ammonium nitrate, and picric acid. Even in peace-times a fair proportion is used for explosives, especially of the so-called "safety" kind, for mining and quarrying, which usually contain ammonium nitrate.

A rapidly growing use for pure nitric acid is in connection with artificial silk and leather, photographic films and all forms of cellulose and imitation ivory. The dye-stuffs industry may be said to depend largely on it and on supplies of sodium nitrite.

About one-third of the ammonia production is used as ammonia sulphate, and one-quarter is for cold storage plants and for the manufacture of artificial ice. One-third is used for the manufacture of soda ash, ammonium chloride and sodium cyanide; about one-eighth goes into the explosive industry, principally for the manufacture of ammonium nitrate; and the remainder is used for miscellaneous purposes.

INCREASE IN REQUIREMENTS.

Table 1* gives the world's production of fixed inorganic nitrogen, and it will be seen that in eight years the output doubled and in eleven years it trebled. This enormous rate of increase means that in another half century the demand will be overwhelmingly greater, and I believe it will be largely met by factories where various processes of fixing atmospheric nitrogen are carried on.

* For the Figures in this and several other Tables I am indebted to a Report on Fixation and Utilisation of Nitrogen published by the Government Printing Office, Washington, in 1921.

TABLE 1.—*World's production of fixed inorganic nitrogen in metric tons.*

	1909	1913	1917	1920
Chilean nitrate	300,000	390,000	392,000	500,000
By-product ammonia	212,000	343,000	364,000	410,000
Atmospheric nitrogen:				
Cyanamid process	2,500	60,000	200,000	325,000
Arc and miscellaneous	3,000	18,000	30,000	33,600
Haber Ammonia process	....	7,000	110,000	308,000
Total	517,500	818,000	1,096,000	1,576,600

The increase is due to

(1) Exhaustion of virgin soils of the world by continued cropping.
(2) Familiarity of farmers with artificial fertilizers and their desire to raise greater crops per acre.
(3) Reduction of animal manure due to mechanical traction.
(4) Use of cottonseed meal, etc., for foodstuffs instead of for fertilizers.
(5) Normal increase of population of world and higher standard of living.
(6) Increase in number of wheat and meat eaters by changing status of native races.
(7) Increase in industries that depend on nitrogen compounds, such as dyestuffs, explosives, celluloid, etc.

The problem of economical nitrogen fixation has already reached national importance, and it will become more international as time goes on, for the people of the world must be fed. Any steps taken to improve processes for fixation of atmospheric nitrogen are of prime importance to all countries.

of sulphate of ammonia, Great Britain is ahead of France and the United States. Canada is relatively high in the list because of a cyanamid factory at Niagara.

Lightning storms* are estimated to bring down about 100 million tons of fixed nitrogen a year, but much of it falls into the sea and on mountains, etc., where it is not useful.

The bacteria in the root nodules of leguminous plants fix atmospheric nitrogen, and this method is called by farmers "green manuring."

NUMBER OF PLANTS.

Table III. gives the number of plants for fixing atmospheric nitrogen, and it is of special interest as showing the enormous increase in output since the year before the war.

* The phenomenon, popularly called "ball lightning, may be a mass of nitrogen dioxide gas made by the lightning combining the nitrogen and oxygen in a concentrated form.

TABLE III.—*Plants for fixation of atmospheric nitrogen.*

Process.	Plants	In 1913 Output tons	Plants	In 1921 Output tons
Synthetic ammonia (Haber)	1	7,000	2	300,000
Calcium cyanamid	15	60,000	35	266,000
Arc	7	18,000	12	35,000

SOURCES OF INORGANIC NITROGEN.

Table II. gives the world's resources for 1920, and it will be noticed that in tons of nitrogen per million of population, Germany, Norway, and Sweden, are ahead of other countries, and also, owing to our production

Since 1921 the General Chemical Co. and Brunner, Mond and Co. have started Haber plants at Syracuse, U.S.A., and Northwich, England. A large modified Haber plant is being completed at Billingham-on-Tees, Claude synthetic ammonia plants

TABLE II.—*Sources of inorganic fixed nitrogen in 1920 in metric tons.*

Country.	Population	By-products of coal.	Atmospheric nitrogen.			Total	Nitrogen per million.
			Arc.	Cyanamid.	Haber.		
Germany	65,000,000	150,000	....	300,000	300,000	570,000	8,760
Norway and Sweden	8,000,000	....	30,000	28,000	....	58,000	7,250
Great Britain	45,000,000	100,000	....	....	....	100,000	2,240
Canada	7,200,000	3,000	800	12,000	....	15,800	2,200
France	40,000,000	15,000	1,300	58,000	....	74,300	1,850
Switzerland	3,800,000	....	....	7,000	....	7,000	1,840
United States	103,500,000	105,000	300	40,000	8,000	153,300	1,480
Austria	51,000,000	10,000	....	22,000	....	32,000	630
Italy	35,000,000	3,000	1,200	18,000	....	22,200	630
Other countries ...	....	27,000	....	20,000	....	47,000	....
Total	....	413,000	33,600	325,000	308,000	1,079,600	....

have been built at Montereau and Béthune in France, and Claude plants are being erected in Belgium, Japan and Spain.

There are seven Cyanamid plants in Germany, two in Austria, nine in France, three in Scandinavia, five in Italy, three in Switzerland, four in Japan, one at Niagara Falls, Canada, and one at Mussels Shoals, U.S.A.

Of arc plants there are two each in Norway, France, Germany and Italy, and one each in Spain, U.S.A., Sweden, Holland, Switzerland and Germany. Also plants are being built at Lake Buntsen, B.C., and at Niagara Falls, Canada.

NITRATE SUPPLIES.

The extent of the deposits of caliche or Chili nitrate is larger than was supposed, but the economic life depends on cost of production. The deposits now being worked are much leaner than those worked 20 years ago, viz., 18 per cent. as against 28 per cent.; also the output per workman is under 50 tons per annum as against about 75 tons. At the same time the costs of labour and of coal have gone up, and these form a large proportion of the cost of mining and treating caliche.

The Chilian Government might reduce the export tax, but are not likely to do so because that accounts for about one-third of the total revenue.

The cost of fixed atmospheric nitrogen, on the other hand, tends to come down as processes are improved and plants increase in size. This is especially the case with the arc process, in which the labour charge is relatively very low and the possibilities of improvement are great.

Before the war Germany used more Chili nitrate than any other country, but does not need any now because of the large nitrogen fixation plants built before and during the war. It is only a question of time when the world's output of nitrogen compounds from the air will so far exceed Chili nitrate, that the control of the fertiliser situation will change over.

Chemical compounds are sold principally on analysis, and business goodwill, etc., count for very little. Therefore, directly the atmospheric product is on the market in sufficient quantity and at a price per unit nitrogen lower than that of Chili, it will not matter how much caliche there may be left in Chili. If it cannot be sold in strict competition farmers will not buy, however efficient the propaganda.

GOVERNMENT ACTION.

During the earlier part of the war it was difficult to get a hearing from our Government for any method of making nitrates from air. This may have been partly due to certain officials nursing the idea that if Germany was prevented from obtaining Chili nitrate she could not carry on.

The situation was also influenced by some who were interested in Chili nitrate and did not want any method of working nitrates from air to be put into operation for fear it would depress Chili nitrate prospects.

At last a small plant to make cyanamid at Dagenham Dock was authorised, and a research was started at University College, London, to investigate the Haber method of making synthetic ammonia.

The Nitrogen Products Committee seems to have been principally occupied in compiling reports, but their recommendation towards the end of the war caused the Government to start building a plant at Billingham-on-Tees to make synthetic ammonia by the Haber process.

The frequent holding up of Chili nitrate supplies by activities of German submarines helped, and I also believe the Government was shamed into making a show of doing something by the U.S.A., French and Italian Governments starting so many fixed nitrogen plants.

In 1920 the Committee issued a voluminous report, and the following are some of the principal conclusions:

(a) That very serious risks are involved in relying upon overseas shipments of raw materials.

(b) That the nitrogen fixation processes are thoroughly reliable, even when installed as emergency measures under war conditions.

The conclusion seems evident that considerations of national safety, of finance, and of utility would force a country to resort to a policy of adopting synthetic methods as an insurance against future emergencies, instead of placing reliance upon the importation of Chilean nitrate.

It is all true, but it came rather late, because two-and-half years before the war began I made the following statement in a paper read before this Society:—*

Nitric acid is, of course, the main constituent of guncotton, dynamite, and smokeless powders, etc., and at the present time we are mainly dependent on over-seas supplies of raw material from which to make the acid. In case of war we should undoubtedly be in a very serious position, for whereas most continental countries have plants for the

* Journal of the Royal Society of Arts, London, Vol. 60, No. 3104, May 17, 1912.

fixation of nitrogen from the air, this country does not make a single ounce.

METHODS OF FIXING NITROGEN.

Broadly speaking, the methods of fixing atmospheric nitrogen may be divided as follows :

First. Nitrates are made by fixing nitrogen and oxygen together without any intermediate steps and without having first to isolate the gases. It includes the arc process which depends on an ample supply of cheap electric power. Also the Hausser explosion process, which depends on cheap coke oven gas.

Second. Cyanamid or cyanide, is made by combing, in which the nitrogen is joined with carbon. It is chiefly represented by the calcium cyanamid process, which requires cheap coke and lime, and electric power, and also pure nitrogen which is usually made from liquid air. Ammonia can be made from the cyanamid.

Third. Ammonia is made by combining nitrogen and hydrogen gases by means of a catalyst. The processes are known by the names of Haber and Claude, and both involve the manufacture of pure nitrogen and hydrogen gases, and the use of exceedingly high pressures.

The ammonia made by the last two methods can be oxidised to nitrate by means of a platinum catalyst. From the point of view of making nitrates the first named is direct and the others are indirect, the cyanamid process being particularly so.

NITRIC AND AMMONIA NITROGEN.

Fixed nitrogen, phosphoric acid, and potash are the three principal plant foods ; and the first is the most important as shown by the relative percentage costs to farmers being 50, 30 and 20. When crops are grown nitrogen is also the first to become deficient in the soil.

All plants take up the nitrogen in the nitric nitrogen form, that is, when it is combined with oxygen. The principal nitrate fertilisers are nitrate of soda $Na. NO_3$ and nitrate of lime $Ca (NO_3)_2$. They are known as quick acting fertilisers.

The other kind of fertiliser, namely ammonium sulphate $(NH_4)_2\ SO_4$, has its nitrogen in the ammonia nitrogen form, and as this has to be changed into nitric nitrogen in the soil before plants can take it up, it is slower acting. It is much used for fertilising rice in paddy fields.

Ammonia nitrate, $NH_4\ NO_3$, has the nitrogen in both forms and very concentrated because it contains 35 per cent.

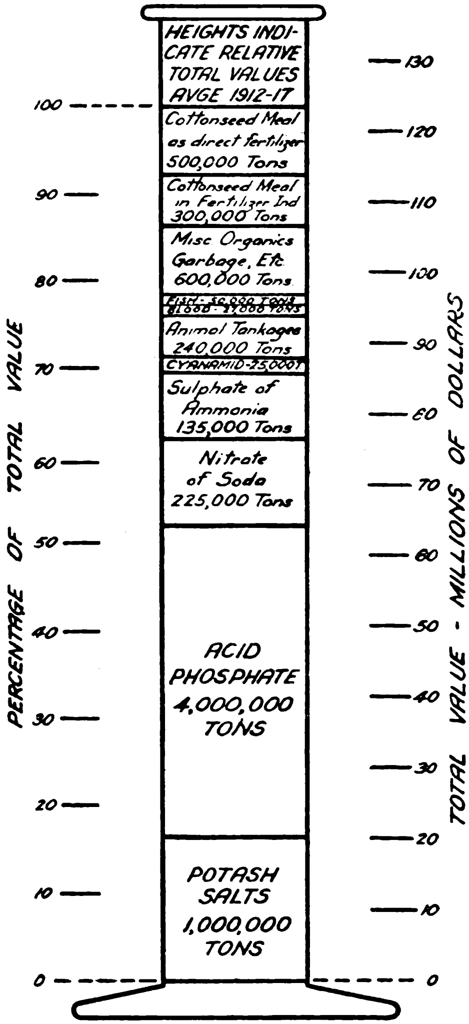

FIG. 1.--Proportions of Mixed Fertiliser used in U.S.A.

This diagram indicates the various materials which are used in the States to make up what is called a mixed fertiliser. It was used as evidence by Mr. Washburn at an enquiry of the U.S. Senate in 1919, and incidentally it shows how relatively small is the quantity of cyanamid that can be employed in such a mixture.

Fig. 1 is interesting as showing the various materials that go towards making a mixed fertiliser, such as used in the United States.

Cotton seed meal is used, but the tendency is to use less of it and make up with more of the other fertiliser materials. It will

be noticed that the nitrogen is partly ammonia nitrogen and partly nitric nitrogen with a small amount of cyanamid nitrogen.

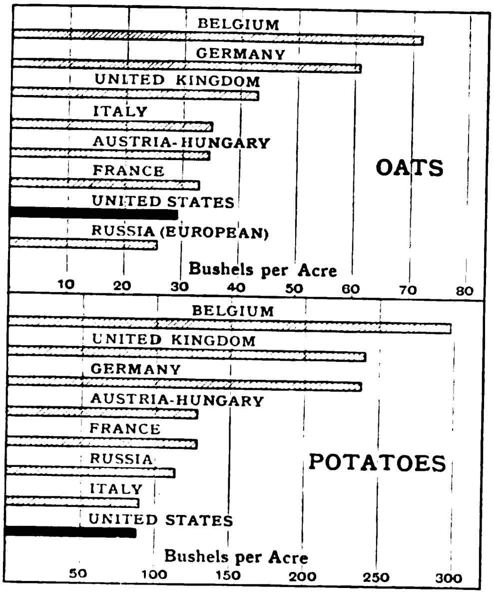

FIG. 2.—Crop Production per Acre in Principal Countries in 1913.

This shows in a striking way the great differences in the crops obtained by farmers of different countries. The reason why Belgium and German farmers obtain greater crops is mainly because they use more fertilizer. Farmers in other countries could do as well, but they must have ample supplies of cheap fertiliser. The periodical famines in India, Russia, etc., are due to very low crop production.

It will be seen from Fig. 2 that in some countries the output per acre is extremely low; for example, in Australia, parts of Canada, and U.S.A., and India, the yield in bushels of wheat per acre is only about one-fourth of the yield in countries like Belgium, where large amounts of fertiliser are used.

ARC FURNACES.

The electric arc process for fixing atmospheric nitrogen depends on the passage of ordinary air through an arc flame, which causes the nitrogen and oxygen to combine as nitric oxide NO. This afterwards takes up further oxygen to become NO_2, which can then be combined with water to form nitric acid HNO_3, or with sodium compounds to form sodium nitrate $NaNO_3$, or sodium nitrite Na NO_2.

I dealt with the history and the principles underlying this process in a paper, *The Manufacture of Nitrates from the Atmosphere*, read before this Society, May 15th, 1912, so I propose now to pass on to a consideration of some details of electric furnaces which are used.*

The types of furnaces can be grouped according to the way in which the arc flames are formed, namely :—

(1) Those which have a mechanically moving part—viz., the Bradley and Lovejoy (U.S.A.) and the Island furnace (Canada);

(2) Those which have a magnetic field to direct the arcs—viz., the Birkeland-Eyde (Norway and France) and the Moscicki (Switzerland);

(3) Those which have a rod-like standing arc—viz., the Schonherr (Norway) and the Wiegolofski (U.S.A. and Canada);

(4) Those which depend upon air currents to direct the arc—viz., Pauling (Austria) and the Heckenbleckner (U.S.A.). All the above require single-phase alternating current, and, therefore, have to be used in sets of three, on a three-phase circuit.

Before the war I designed a furnace which used the three alternating currents in one reaction chamber and several have been made. The Nitrum Company, Switzerland, have also brought out a 3-phase furnace, which works very successfully.

BIRKELAND EYDE FURNACE.

This type was the first to be used commercially, and in twenty years the size has been increased from 50 K.W. to 4,000 K.W. For some time 1,000 K.W. was the standard, but it has been found to be easier to make and to operate the 4,000 K.W. size, and they also give higher yields because they are more efficient. A few hitherto unpublished details will be of interest.

The central part of the furnace walls consists of blocks 18 inches diameter and 3 inches thick, made of a material called Dynamidon, having the following composition :—50 % SiO_2 46 % Al_2O_3; 3% Fe_2O_3; and a trace of CaO.

The outer parts of the walls have numerous holes $\frac{5}{8}$-inch diameter for the air to pass through, and are made of Chamotte, a mixture of burnt English clay mixed with ground quartz. It is tempered into the furnace body and thoroughly dried.

* See Paper on Nitrogen Fixation Furnaces by E.K.S., read before the American Electro Chemical Society, September 30th, 1918.

The electrodes are of pure electrolytic copper, two inches diameter ⅛-inch thick and 8 feet long. They are bent into U shape and a sparking tip is brazed on the end. About a foot distance from the tip the pipe burns flat, and when too thin the electrode is removed, the burnt end is sawn off and a new piece brazed on.

The insulator which carries the electrode is of an artificial granite material made into a sphere and cast round the tubes.

Power of Auxiliaries.

In the first installation at Notodden there were five blowers to supply air to the furnaces and move the gases through the absorption towers. In the later installations as at Pierrefitte only one gas exhauster is used, and consequently the motors for working the plant only absorb about four per cent. of the total energy.

About one per cent. of the total supply is used in energising the reactance coils which are necessary to steady the arc flames. The power factor of the earlier Norwegian plants was only .6, but it has now been raised to .80 by means of a method devised by Mr. Lilienroth. When starting up the electrodes are brought together momentarily, but the rush of current is limited by the reactance. It is 40 per cent. above normal at .7 power factor, thus $1.0 \div .7 = 1.4$.

Less than half of one per cent. is required as direct current for energising the magnet coils, and these coils are kept cool by passing air through them on its way into the furnace. It is important that the magnetic effect of each coil should be exactly the right strength so that the flame spreads out into a flat disc, and for this purpose a regulating resistance is provided in each coil.

Advantages of 3-Phase Working.

Although single phase furnaces work well and give yields which long experience shows are sufficiently high to make the process a great commercial success, as in Norway, yet I have always been of opinion that better results should be obtained by working each furnace as a 3-phase unit.

One would not, for example, try to use three single phase motors in place of a 3-phase motor any more than use three single crank engines instead of a 3-crank engine. So why use three single phase furnaces if a furnace having the 3-phases together can be made to work ?

The electrical advantages of a 3-phase furnace are: it functions as a single unit, with one switch and set of instruments. The three arc flames maintain each other, for there is always current flowing between the electrodes whereas with single phase there are two moments in every period when no current flows.

Cooling water loss varies with the number and the size of the electrodes, and as two electrodes are the least that can be used for any one furnace, it follows that three single-phase furnaces must have six electrodes, while a 3-phase furnace of the same total power has only three. The heat absorbed in cooling three electrodes of one furnace is less than for cooling six electrodes of three separate furnaces. Also, doubling the number of electrodes means doubling the pipe connections, fittings and electric cables ; and as the water connections must be connected to the high tension supply, it is well to have as few as possible.

Three electric arc flames acting together in one reaction chamber should give a higher temperature than three separate arcs each within separate walls which radiate heat. A 3-phase furnace of 3,000 kw. has considerably less wall area and therefore less radiation and other losses than three 1,000 kw. single-phase furnaces.

Kilburn Scott Furnace.

The following description is from Appendix V., p. 241, of the report of Nitrogen Products Committee :—

The lower part of the furnace where the air is admitted is in the form of a conical reaction chamber, three water-cooled electrodes being spaced around the walls at 120° apart. The arc is started by means of pilot sparks between the main electrodes and an auxiliary electrode situated in the gap between the converging tips of the main electrodes just above the air admission pipe. The high frequency pilot sparks which are in an independent high tension circuit are conveniently maintained during the operation of the furnace, and it is stated that they improve the yield and help to maintain continuity of working. The upward current of air, which is advantageously pre-heated to about 250° C. blows the three-phase arc into a flame which spreads up the diverging electrodes. The employment of an auxiliary magnetic field for spreading the arc as in the Birkeland-Eyde furnaces is thus rendered unnecessary.

To promote the rapid cooling of the furnace gases and minimise the dissociation of the nitric oxide formed, the reaction chamber is surmounted by a steam boiler which constitutes the roof of the furnace and is earthed in order to avoid electrical

leakage. The metal of the boiler is not attacked by the furnace gases at the temperatures involved. The steam raised in cooling the gases represents a considerable economy in working, and it is claimed that the regenerative gain by utilising the steam in a mixed pressure turbine will amount to over 10 per cent.

A three-phase furnace is claimed to have a special advantage as regards the intimacy of contact between the whole of the air and the arc, owing to the fact that a revolving arc is continuously maintained by the current always flowing in the phases, whereas in single-phase furnaces the energy varies from zero to a maximum twice in each alternation.

As the result of trials with a small experimental furnace, it is considered commercially feasible to obtain yields about 50 per cent. higher than the usual yield of 50 to 60 gms. of HNO_3 per k.w.-hour obtained with standard types of single-phase furnaces. (*Journal of the Society of Chemical Industry* 1915, Vol. 34, No. 3, and 1917, Vol. 36, No. 14.)

There is also a reference to a furnace of 300 k.w. capacity which it is suggested did not fulfil expectations. This furnace was installed at the works of Kynoch's, Ltd., Birmingham, during the war, and tested by grammes per kWh. My confidence is based on the fact that I have obtained on several occasions over 100 grammes per kWh with an input of 120 kWh, which, owing to limitations on the plant, was the average power available during the research."

Fig. 3 shows the lay-out of the experimental plant at Holford, Birmingham, and Figs. 4 and 5 show the details of a 1,000 k.w. furnace, which was built in U.S.A.

THEORETICAL CONSIDERATIONS.

Table IV. is of interest as it epitomises actual experience gained by working the arc process in Norway. The figures are approximate percentages, and show that of the energy put into the furnaces 2·6 per cent. goes into the nitric oxide gas, and 0·4 per cent. into the furnace magnet coils. Also of the 85 per cent. that goes into the boilers, 72 per cent. is recovered as steam, and 40 per cent. of this steam can be used regeneratively in steam turbine generators, and the rest in concentration of products.

TABLE IV.—*Energy Changes in various parts of arc process. Figures in per cent.*

Plant.	Energy consumed.		Energy given out.	
Furnace	100	in arc	10	in radiation
	2.6	in gas	6	in cooling water of electrodes
	0.4	in magnet coils	87	in gas
Boiler	85	in gas	3	in radiation
	7	in feed water	72	in steam generated
			17	in gas
Preheater	16.8	in outgoing gas	2.6	to incoming air
			14.2	in gas
Aluminium coolers	14	in gas	8	to cooling water
			6	to gas
Oxidation tower	6	in gas		
Acid absorption towers	4.5	in acid	28.3	in vapour driven off
	25	in steam made above	1.2	in acid
Alkaline towers	1	in nitrate nitrite	9.7	in vapour driven off
	9	in steam made above	0.3	in sodium nitrate
Auxiliary apparatus	4		0.2	in blowers
			0.4	in magnet coils
			1.6	miscellaneous
Steam from boilers	75		40	in steam turbines
			33	in concentration
			2	in boiler pumps

Mr. H. Robinson, who wrote to the Secretary of the Nitrogen Products Committee as follows :—

"The final results of this furnace proved the Kilburn Scott claim of 50 per cent. higher yield to be quite sound, and I, personally, have no doubt that this type of furnace will give more than 90

Table V. gives temperatures and pressures in various parts of an arc process plant as used in Norway and France, and also the time in seconds which the gas takes in passing through the various parts of the plant.

TABLE V.—*Temperature, Pressure and Time.*

Part of plant.	Temperature of gas in deg. cent.	Pressure drop in inches of water.	Time of gas in in section in seconds.
Furnaces	25 to 1100	5.4	2
Boilers	1000 to 300	4	
Preheaters	300 to 175	2.5	30
Aluminium cooler	175 to 40	7	
Oxidation tower	40 to 56	1	75
Acid absorption towers	56	17	190
Alkaline towers	56	7	90

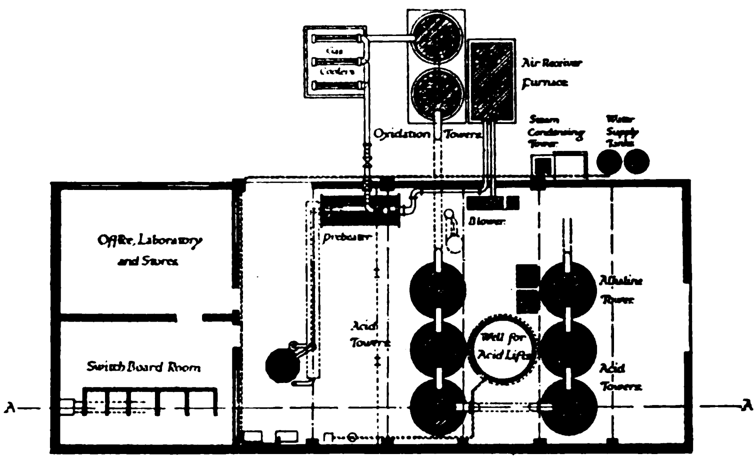

FIG. 3.—Arc Plant at Holford, Birmingham.

Built during the war by Kynocks, Ltd., to test the yield of a 300 k.w. Kilburn-Scott 3-phase furnace and to make investigations in problems of absorption, etc. The furnace was tested with about 120 k.w. at 5,000 volts and 50 periods.

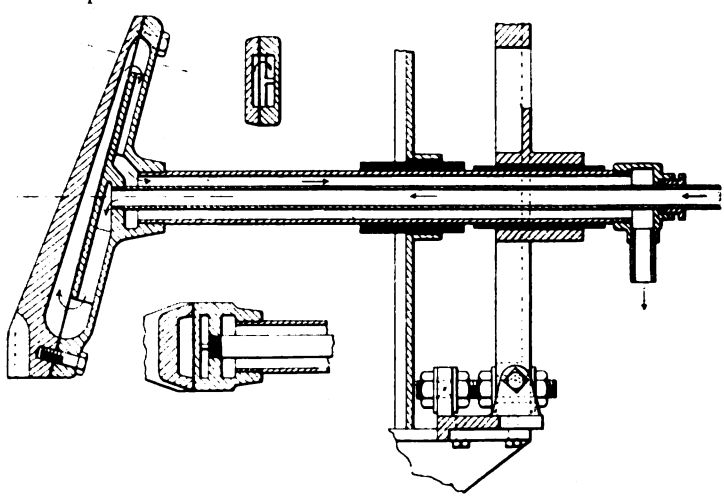

FIG. 5.—Electrode for 3-phase Furnace.

The electrode is made of two castings, the front being of copper and easily replaceable. Cooling water passes into and out of the electrode through steel pipes, as shown by the arrows, and it is fed to the electrode through a 6ft. length of insulation piping part of glass and part of rubber.

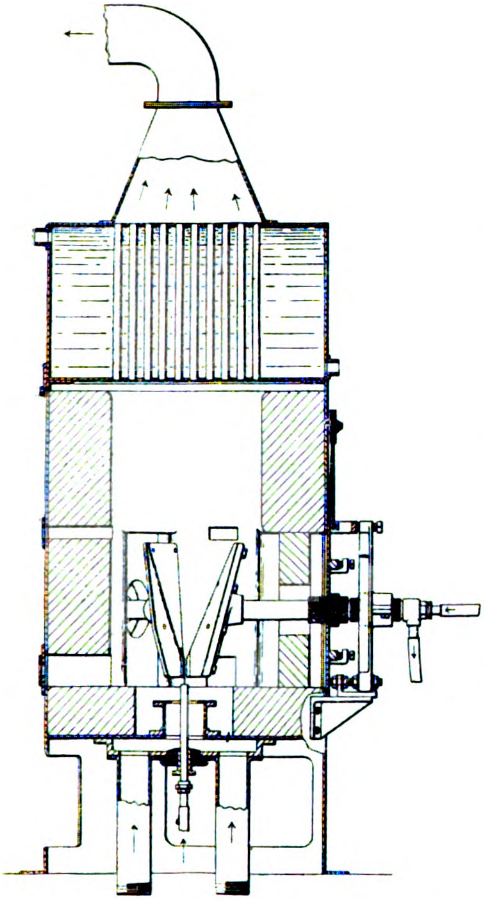

FIG. 4.—Kilburn-Scott 3-phase Furnace.

A furnace of this design was built in U.S.A. about the end of the war. It is for 1,000 k.w. at 5,000 volts. Air is fed in by two pipes and the small central one is insulated and carries the pilot sparking wire. The electrodes are at 120 degrees, and are adjustable by screws outside the furnace wall. The roof is water cooled.

EFFICIENCY OF THE ARC.

The arc process is the simplest method of nitrogen fixation, but its main handicap is the large amount of power necessary for fixing the nitrogen. The arc furnaces, as ordinarily used, require 67,000 kilowatt hours per ton of nitrogen produced, and a reduction in this power consumption is desirable.

The essential reaction in the arc process is $\frac{1}{2}\ N_2+\frac{1}{2}O_2=NO-21,600$ cal., where the heat of reaction at 25°C. is in the neighbourhood of 21,600 calories. The actual energy input used in producing one molecule of nitric oxide in existing arc plants is about 865,000 calories, and this difference in calories has led to the belief that the arc process is very inefficient.

To calculate thermal efficiency, however, the energy must not be compared with the heat of reaction at room temperature, but with the amount of heat necessary to raise the air to the reaction temperature plus the heat necessary to make the reaction occur. The largest amount is used in heating the air to the reaction temperature, and thus the amount actually absorbed in the reaction is only a small fraction of the total. On this basis the thermal efficiency of existing arc processes is much higher than is generally supposed, perhaps about 50 per cent.

ELECTRICAL OR THERMAL EFFECT.

There has been considerable discussion as to whether the fixation of atmospheric nitrogen in the electric arc is an electrical or a thermal effect or both. Some maintain that for a given temperature the yield would be the same whether the temperature was obtained by an electric arc or by some ordinary steady flame as, say, given by gas.

Personally, I do not think it would be so, for there are other phenomena besides heat in the electric arc; ionization, for example, which appears to have the effect of disrupting the nitrogen molecules and so facilitating their combination with surrounding oxygen. It is conceivable also that electrical stresses due to the high voltages and the magnetic fields set up by the currents may have effect.

Prof. Cramp found that there was an increase of nitric oxide when ozone was added to the air, and I suggest that ozone O_3 and the corresponding polymer of nitrogen, which Sir J. J. Thomson calls N_3, are formed momentarily, and then, dissociating, the nascent atoms of oxygen and nitrogen combine.

Dr. C. P. Stemmetz states in "Chemical and Metallurgical Engineer," Vol. 22, that:

"The evidence is strongly in favour of the assumption that the effect on the arc is primarily an electrical one, a dissociation of the molecules into free atoms and then re-combination of these by the probability law limited by the temperature stability of the resulting products."

Mr. J. L. R. Hayden gives, in the Transactions American Inst. Elec. Engs., 34, 613, results of experiments with electrodes of various materials which produced nitric oxide in the following order:—

Electrodes.	Concentration.	Boiling Point (Arc Temperature).
Iron	Highest	2450 deg. C.
Titanium	———	2700 deg. C
Carbon	———	3600 deg. C.
Copper	Lowest	2310 deg. C.

Although carbon had the highest arc temperature it was relatively inefficient in producing nitric oxide. Iron and copper, which give approximately the same arc temperature, are at opposite ends of the scale in producing nitric oxide.

Another experiment with mercury arc, showed that it was easily possible to get concentrations above those representing thermo-dynamic equilibrium.

Profs. Haber and Koenig, who have made very complete investigations, have expressed the opinion that the nitrification of the arc discharge is at least partly a direct electrical effect.

Dr. Maxted states in the Proceedings of the Society of Chemical Industry for April 15th, 1918:

"Purely thermic interpretation of the nitrogen oxide reaction depends on a large extrapolation from lower to higher temperatures, and assumes that no latent factors cause increase or decrease in the observed temperature coefficients."

Dr. C. P. Steinmetz.

In discussing a paper which I read before the *American Institute of Electrical Engineers*, June 27th, 1918, Dr. C. P. Steinmetz said:

The reason why I have confidence in the arc process is not only due to the absence of the need of any other raw material but air, which makes it specially suitable for use anywhere where power is available,—as pointed out by Mr. Scott, at the coke oven for instance—it is not only the possibility of the use of intermittent power, which holds out the hope of developing a powerful nitrate industry in peace times, but it is also the vast possibility of increasing the efficiency of nitric acid production by the arc process, over that reached in the Norwegian plants. Under favourable conditions, I understand, the present efficiency is from 60 to 80 grams per kilowatt hour. The theoretical efficiency of nitric oxide production is 2500 grams of NO_3H per kilowatt-hour, so that the present best results are an efficiency of 3 per cent.

You can realize, therefore, the vast possibilities there are in increasing the efficiency, and if at an efficiency of only 3 per cent. the process has become commercial under favourable conditions, we can see that there are possibilities in this method which will bear considerable efforts being made in studying the development further, and carrying on the development, which I am sorry to say has practically been neglected since the early pioneer days of Charles Bradley, the electrical engineer, who started a plant at Niagara Falls, but failed, due to the cost of investment in his particular method being out of proportion to the returns.

I want to conclude by repeating that my study of the problem—and I have been closely interested in it, not only theoretically, but I have done considerable experimental work during the past twenty years or more—has led me to the conclusion that while the cyanamid process may have immediate use by being the quickest available, the process which I consider as the most promising in the final solution of the problem is the direct or arc process.

Later he contributed some very important articles to the *Chemical and Metallurgical Engineer*, Vol. 22, in which he discussed the physics of the arc furnace, and suggested a way of improving it. He thinks that instead of 1½ per cent. concentration of nitric oxide, as much as 4.45 per cent. might be expected. Such a concentration would very greatly reduce the size of the absorption towers.

He suggests working with air under pressure, and terminating the arc in the throat of an expansion nozzle, and says:

Water cooled nozzles of high ferro tungsten would probably stand the temperature for a considerable time, especially if the throat is made replaceable. A turbine wheel in front of the nozzle would further cool the gases and abstract their velocity without any temperature rise due to destruction by their kinetic energy. A steel wheel would probably do.

Possibilities of Improvement.

There are several ways in which it is known positively that the arc process can be improved. One is to feed the arc flame with air enriched by oxygen.

A 50-50 mixture of nitrogen and oxygen instead of a 79·21 mixture as in air, gives 20 per cent. increase in yield, thus

$$\frac{\sqrt{50 \times 50}}{\sqrt{79 \times 21}} = 1{\cdot}20$$

Also the addition of oxygen up to a 50 per cent. mixture is equivalent to increasing pressure 2.4 times, thus $50 \div 21 = 2.4$.

This is equivalent to a pressure of $14{\cdot}75 \times 2{\cdot}4 = 35$ lbs. per sq. inch, but the effect is obtained without actually putting the walls of the furnace under that pressure.

With a re-entrant system of piping very little make up oxygen is required to keep up a 50-50 mixture. Thus for a 10,000 kw. plant passing 70 cub. ft. air per hour, and giving a concentration of 1·5 per cent.

of nitrogen dioxide, the make up oxygen works out at only 1,450 cub. ft. per hour.

There would be no particular difficulty in making furnaces to work at pressures of upwards of 100 lbs., and the effect should be beneficial.

Air at high pressure has a greater insulating value than air at low pressure, as shown by the fact that sparking between the metal quadrants of an electrostatic voltmeter may be stopped by merely increasing the air pressure. Also at high altitudes the corona effect on transmission lines is more pronounced.

Absorption of Gases.

One of the principal problems to be solved in the arc process is how to cut down the great cost of, and the space occupied by, the absorption towers. When dilute nitric acid is being made these acid towers represent 35 per cent. of the total cost, and the alkaline towers 8 per cent.

If the usual concentration of about 1½ per cent. be doubled the acid towers would come down to about one-fourth the size and alkaline towers are not required.

Again, by using high pressures, as in the Hausser explosion process, and making special towers of acid proof metal, the capacity of the towers might be cut down very much; for example, at three atmospheres M. Hausser claims that the size can be about one-fiftieth of what is required at ordinary atmospheric pressure.

When sodium nitrite only is required, the towers are comparatively small, even with gases at 1·5 per cent. concentration. They enter the alkaline absorption towers at about 250 deg. C., because at this temperature only about half the nitric oxide has changed to nitrogen dioxide and the mixture when absorbed by sodium carbonate or caustic soda gives sodium nitrite without any nitrate. Alkaline absorption towers are much smaller than those for making nitric acid, and they are also cheaper to build because they are made of steel plates.

Considerable quantities of sodium nitrite are required for the aniline dye industry, and it is also used for drugs and for the pickling of meat, etc.

Fig. 6 shews a form of cell packing which is used in this country. In U.S.A. the spiral packing ring of the Chemicoe Construction Co. is much used.

Experiments have been going on at the Nitrogen Research Laboratory at Washington, D.C., into the use of silica gel as an absorbent of nitrogen dioxide. To obtain satisfactory adsorption of NO_2, it is necessary to pack the tube and the nitrogen peroxide container in ice. The average of 63 runs gave an adsorption of 63.86 per cent., and the adsorption capacity of the gel was undiminished at the end of the runs.

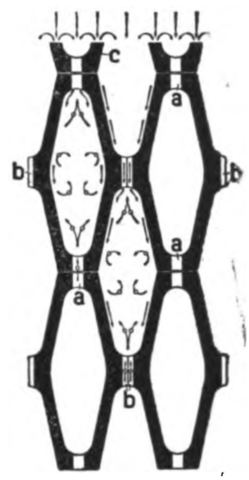

Fig. 6.—Goodwin Type Cells for Absorption Towers.

When nitrogen dioxide gas has only low concentration, large free space is of paramount importance—scrubbing or contracting surface coming second. In these cells the gases continuously change velocity, and the resulting mixing action brings fresh particles of gas into contact with the wetted surface. The movement of the gases in a tower averages about 40 feet per minute, but by means of the slots in the cells the velocity changes momentarily to higher values, and this gives good mixing action. The amount of liquid carried by the corrugations on the surfaces of the cells is about ½ pint per cub. ft. Flushing is usually at ½ minute intervals.

Dr. B. Lambert, of Oxford, has done a good deal of research work on the adsorption of gases by gels and also by activated charcoal and he thinks that low concentration nitrogen dioxide might be dealt with commercially in that way. Also he sees possibilities in a direct reaction by the gas with specially prepared briquettes of quick lime. A process by Prof. Scholesing for making nitrate of lime direct from the gas and quicklime, has been tried at Notodden in Norway.

DESCRIPTIONS OF PLANTS.

The plants at Notodden, see Fig. 7, of the Norwegian Hydro-Electric Nitrogen

FIG. 7.—Nitrate Plant at Notodden, Norway.

The original plant has 35 Birkeland Eyde furnaces, each taking 900 k.w. single-phase alternating current. The magnet coils take 25 ampéres direct current. The second plant shown in this figure has 4 Birkeland Eyde furnaces of 3,000 k.w. each, one being spare.

Co., utilise about 60,000 k.w. from two water falls. A plant at Rjukan I. utilises 110,000 k.w. from a single water fall, and has 96 Schonherr furnaces, 800 k.w. each, of which 72 are kept in continuous operation by eight generators; also 6 Birkeland Eyde furnaces of 3,500 k.w.

The second at Rjukan II. which was completed during the war, also utilises about 110,000 k.w. from a second power station which uses another head of the same waterfall as Rjukan I. It has 36 Birkeland Eyde furnaces of 4,000 k.w. each, supplied with current from 10 water turbine generators.

The 4,000 k.w. steam turbine generators which work regeneratively, are used to supply energy back to the furnaces. They are operated by the steam raised by gases from the furnaces.

The gases from Rjukan II. are piped to adsorption towers at Rjukan I. by 8 aluminium pipes 3ft. in diameter and about ¾ miles long. These pipes serve to cool the gases and they also provide space in which the NO gas can oxidise to NO_2.

All the gases of the two plants go through 60 absorption towers built of granite, each ten sided, 20 feet across and 75 feet high, and packed with a special Norwegian quartz free from iron.

PLANT AT PIERREFITTE.

During the war the Norwegian Hydro Electric Nitrogen Co. built a plant at Pierrefitte in France to utilise 8,000 k.w. and to produce about 4,000 metric tons of nitric acid (100 per cent.) per annum, or, 11 tons per day. The layout is shown in Figs. 8 and 9.

Current was supplied from a hydro electric station of the Midi Railway Co., equipped with alternators, giving 4,300 k.w. 3-phase, 50 cycles and 9,500 volts.

The furnace room has four Birkeland-Eyde single-phase furnaces, 4,000 k.w. size and 10ft. diameter, one being spare. The electrodes are 1 inch internal diameter, water cooled, and the average life of an electrode is four weeks. The electro-magnet coils in the side of the furnace are supplied with direct current obtained from a rotary converter.

Air enters the reaction chamber through ⅜ inch diameter holes in one wall of the furnace. The gas and air from the furnaces raise steam in two Babcock water boilers and the temperature is reduced from 950° to 250° C. Water coolers or refrigerators in the open air cool the gases to 40° C., at which they pass into the four acid absorption towers. These are ten-sided, made of slabs of Norwegian granite, clamped by iron bands, 26.925 metres high inside and 7.3 metres across. The thickness of the wall is 250 mm. one-third way up the tower and diminishes in steps to 200 mm. The towers are mounted on concrete piers and the filling consists of pieces of Norwegian quartz free from iron.

Liquor is circulated by a compressed air montejus lined with acid-resisting stoneware and having a capacity of 400 litres. Circulation is intermittent, the montejus being emptied every two or three minutes. The circulation works out at about 10,000 litres of acid per hour and the acid from the first tower is about 30 per cent. strength.

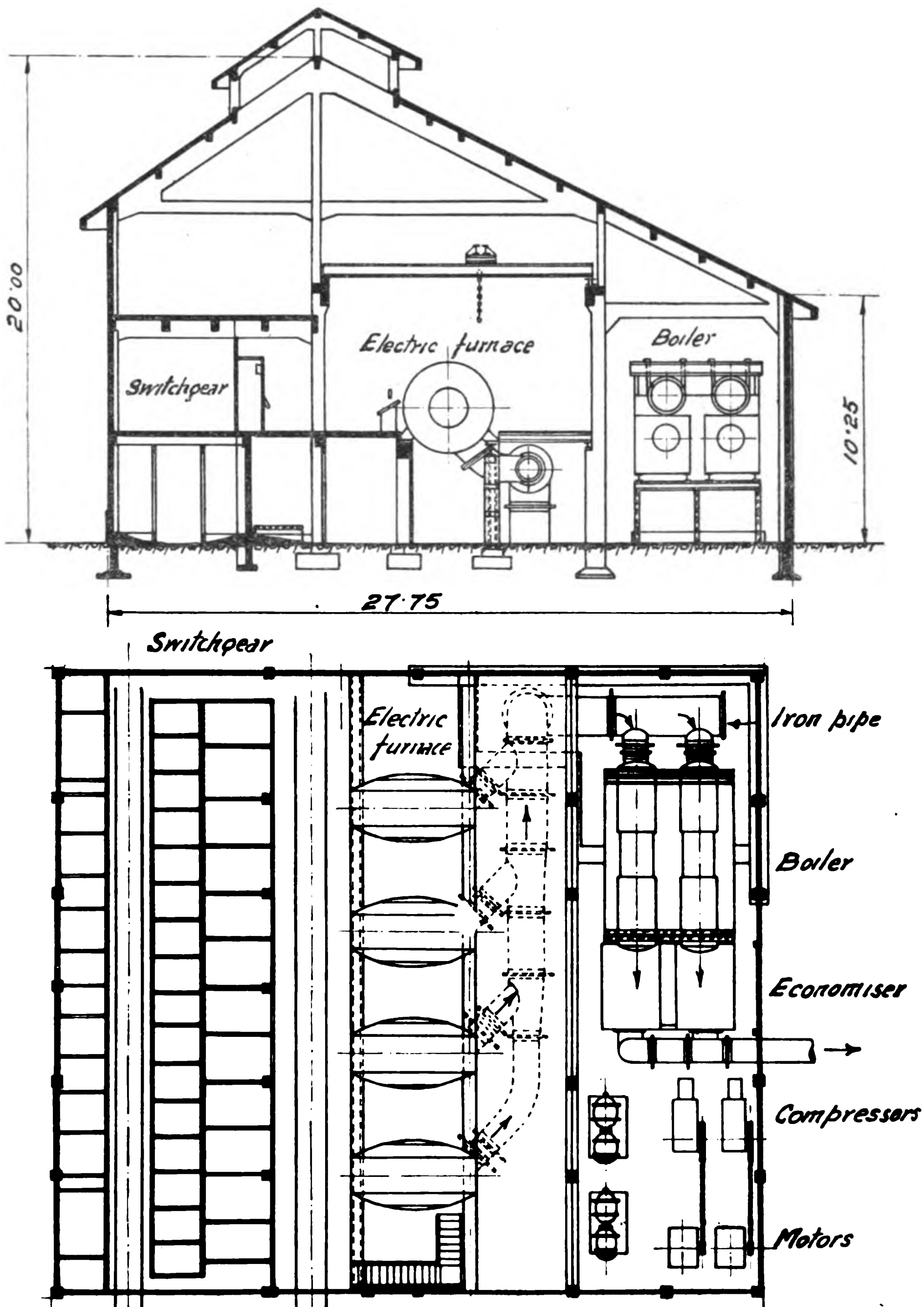

FIG. 8.—Furnace Room of Arc Plant at Pierrefiette, France.

The furnaces are of Birkeland-Eyde type, 4,000 k.w., each one being spare. Gases leave the furnaces at about 1,000 deg. C. and the boiler at 250 deg. C. The air and gases are drawn through by an exhauster.

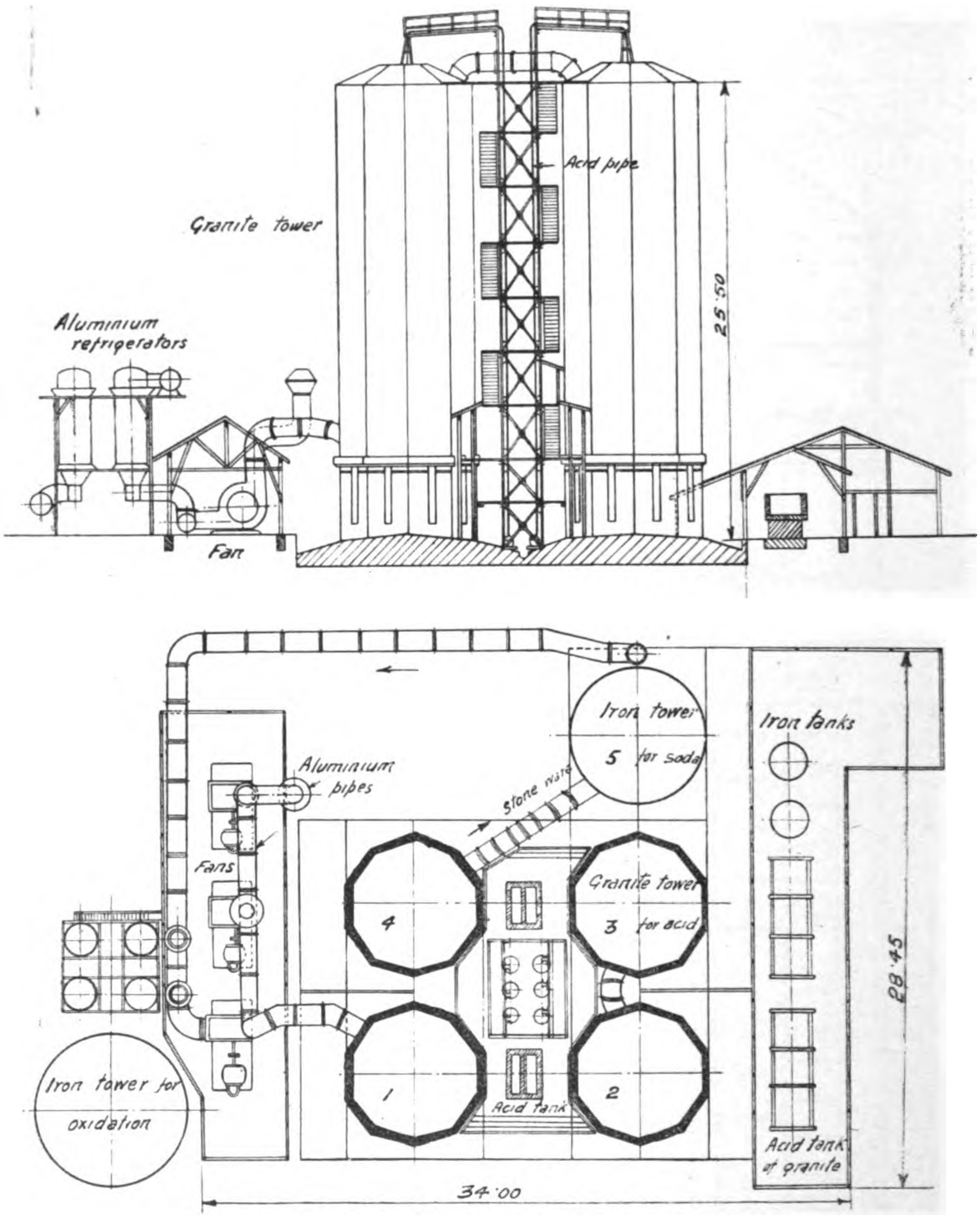

FIG. 9.—Absorption Plant at Pierrefiette, France.

This plant was designed and built by the Norwegian Hydro-Electric Nitrogen Company during the war, and was for making nitric acid of 96 per cent. strength. The towers are of granite packed with pieces of Norwegian quartz.

It can be raised to 52 per cent. by slower circulation.

The alkali-absorption tower is made of steel plates, and packed with quartz. Through this a solution of sodium carbonate containing about 2 per cent. of caustic soda is passed and the resulting sodium nitrate has a strength of 30 per cent.

Reckoned on nitric acid and sodium nitrate made, the yield works out at 550 kilogrammes of HNO_3 per k.w. year used in the furnaces and motors. Referred to power measured at the switchboard and used solely for the operation of the furnaces, the

yield is 560 kilog. HNO_3 per k.w.-year or 63 grammes per k.w.-hour.

Concentration of Acid.

Acid from the towers is pumped to a reservoir from which it passes down four granite towers each 10ft. in diameter and 50ft. high, lined with acid-resisting brick and packed with broken quartz. It meets steam from the weak acid concentrating plant and receives a preliminary concentration. This acid has also been preheated before entering the towers by means of waste steam from another part of the plant. The acid concentrator consists of four steam-jacketed tubes of Tantiron; steam at 8 kilog. per sq. centimetre is passed through the jackets and evaporation is effected at ordinary pressure. Each tower is connected with a battery of four of these concentrators.

The above brings the acid up to 60 per cent. It is then collected in four reservoirs and pumped to a reservoir at the top of the building, whence it flows into two granite octagonal towers about 8ft. in diameter and 30ft. high, one being a reserve. Into this tower sulphuric acid is run from a tank, and nitric acid of 96 per cent. is then distilled over and condensed in aluminium S pipes placed between the two towers. The strong acid is run down a small granite tower through which a current of compressed air is passed to remove oxides of nitrogen.

The diluted sulphuric acid (60 to 65 per cent.) is reconcentrated in a plant similar to that used for making 60 per cent. nitric acid, except that it is worked under vacuum, which vacuum is maintained by a vertical fall pipe and condensing jet.

Sodium nitrate is made in two ways, first by treating tower acid with sodium carbonate, the CO_2 being removed by fans together with some oxides of nitrogen; second by treating nitrite solution from the alkali tower with tower acid in a granite tank having an aluminium cover, the evolved oxides of nitrogen being aspirated back into the absorption system.

Nitrum Company's Plants.

This company has a 6,000 k.w. plant at Bodio, Switzerland and a 13,000 k.w. plant at Rhina in Germany. There was a third plant of 60,000 k.w. at Merseburg in Germany, but it was blown up during the war.

The furnace utilises three-phase current and consists of a fire-brick-lined steel cylinder having three adjustable water-cooled iron electrodes. Air, introduced tangentially, cools the walls of the furnace

Table VI.—*Products of Arc Process in Norway.*

Product.	Purity.	Content.
Nitrate of soda	98%	20% of Nitrogen
Nitrite-nitrate of soda	....	18.6% of Nitrogen.
Nitrate of ammonia	99.97%	17.5 of Ammonia nitrogen. 17.5 Nitric nitrogen.
Nitrate of soda refined	99.5%	16% of Nitrogen
Nitrate of soda ordinary	96 to 98%	16% of Nitrogen.
Nitrate of potash	99.9%	13.85% of Nitrogen. 46.5% of Potash.
Biphosphate of Nitrogen	....	30% of Phosphoric acid citric soluble. 3 to 4% of Nitrogen.
Phosphate of ammonia	....	60% of Phosphoric acid water soluble. 12% of Ammonia nitrogen.
Nitric acid concentrated	....	98 to 99%.
Nitrate of lime made basic for fertiliser	N_2O_5 50.21% Lime 25.94% Combined Water 23.6%	13% of Nitrogen.

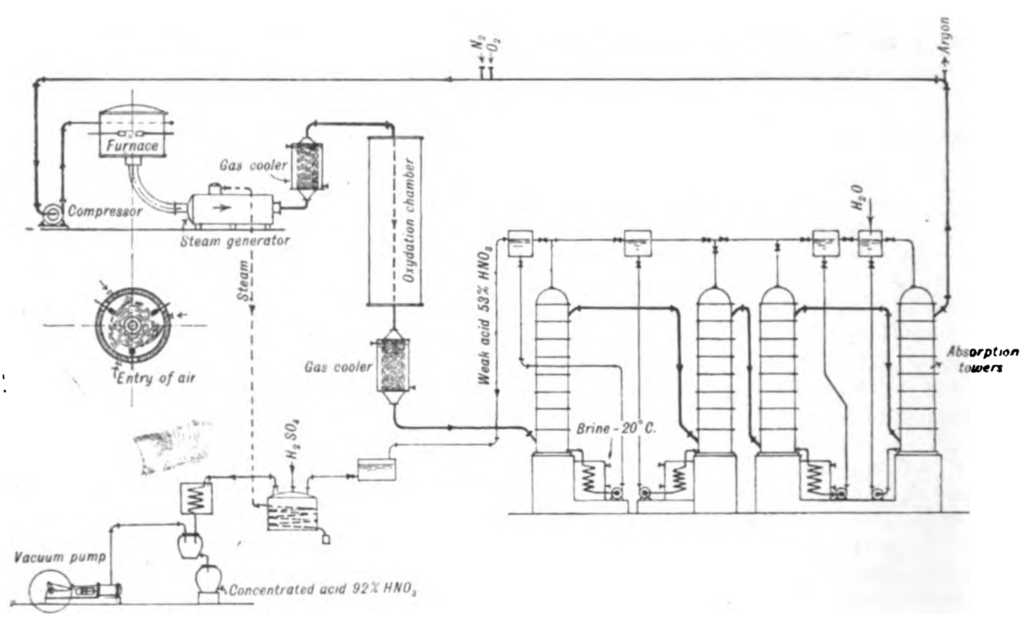

Fig. 10.—Arc Process plant of the Nitrum Company.

The furnace works with 3-phase alternating current and has a disc-like arc flame, which is whirled round horizontally by air and oxygen. The absorption towers are for nitric acid only and they are gas-tight. Any remaining nitrogen dioxide and the uncombined air passes from the last tower back to the furnace, and it is enriched with oxygen to maintain a 50-50 mixture.

before it forms a horizontal disc-like arc flame. The nitric oxide leaves the furnace in the centre of the arc at the point of highest temperature, thus securing high concentration. Fig. 10 is a view of a 3,500 k.w. furnace.

The gases pass out by a water-cooled pipe to a steam generating boiler, and quick cooling of the gas in the above mentioned pipe prevents decomposition of the gases and gives a concentration of from 2.5 to 3 per cent. of nitrogen oxides.

At Bodio the absorption is by means of absorption towers. Owing to the high concentration of the gas and the low temperature and other special characteristics nitric acid of 60 per cent. strength is obtained. There is no alkali absorption as the gas leaving the acid-absorption system does not contain more than 2 to 3 grammes of HNO_3 per cubic metre. The total absorption capacity of the towers used is only about ⅛th of that required for gas having a concentration under 1.5 per cent.

The plant at Rhina has run for seven years and it is of special interest because a gas mixture of half oxygen and half nitrogen is used, this being the only plant which uses oxygenated air on a large scale.

Liquid Nitrogen Dioxide.

The Nitrum Company has developed a method of recovering the oxides of nitrogen from the furnace gases without employing absorption towers. It is done by cooling the gases to a temperature below zero, and the nitrogen dioxide separates out in the liquid form.

The gases are recirculated through the furnace after removal of the nitrogen dioxide, as economy in the consumption of oxygen is an important consideration.

The gases entering the furnace must be dry, because moisture causes a reduction in the yield and lead to corrosion of the cooling plant owing to the formation of nitric acid.

All the power necessary for separating oxygen from the air and for condensing the nitrogen dioxide is obtained from steam raised by heat of the furnace gases.

The liquid product can be stored in steel tanks or cylinders, and marketed for use in different nitrification processes. It can be converted into concentrated nitric acid without the employment of concentrating apparatus by autoclaving with water in the presence of oxygen at a pressure of five atmospheres.

When the Nitrum Company first started this liquifying process, hydro carbons were used to transmit the cold and they caused explosions. In the discussion at end of the last lecture, the late Dr. Harker referred to this and it is therefore important to give the following explanation by the Company —

The explosions which took place in the plants of Zschornewitz and Bodio happened in a part of the system which has now been abandoned. In these plants the furnace gases were cooled to a very low temperature of about 70°C below freezing point, thus freezing out the NO_2 contained in the gas current. To transmit the cold at this low temperature we used either toluol or benzine. Through a leakage in the cooling apparatus a mixture of the organic cooling liquid with the liquid NO_2, was formed which took fire. As this part of the system has been definitely abandoned there is no danger of explosion left.

The Rhina plant is using our patented aqueous absorption, the yield measured at the furnace being about 75-80 gr. of nitric acid (100%) per k.w.-hour. The gas lead to the furnaces has 50% oxygen and 50% nitrogen.

PRODUCTS.

Table VI. (p. 873) gives particulars of the products which are made by the arc process in Norway.

NITRATE OF LIME.

The method of making nitrate of lime in Norway is to take the 30 per cent. nitric acid from the absorption towers and treat it with limestone (carbonate of lime) obtained from the company's mines in the neighbourhood of Skien. The operation is carried out in granite vats, carbonic acid gas is liberated and calcium nitrate remains in solution.

It is then evaporated in Kestner evaporators which are supplied with steam from the boilers, heated by the hot furnace gases. A syrupy solution of calcium is formed which passes on to revolving cylinders which are internally cooled. The nitrate is rapidly solidified, and taken off in leaves, and then crushed and screened to obtain the granular form.

Sufficient lime is added to make the material basic and bring its deliquescence to about that of Chili nitrate fertiliser. This lowers the nitrogen content to about 13 per cent.

Scandinavian farmers use over 70,000 tons per annum of nitrate of lime.

The exports in metric tons of nitrate of lime, sodium nitrate, and ammonium nitrate made by the arc process in Norway, are as follows :—

Year.	Nitrate of lime.	Sodium nitrate.	Ammonia nitrate.
1915	70,927	1,126	9,107
1916	46,001	14,783	59,639
1917	35,932	22,711	63,578
1918	58,625	49,588	49,588
1919	63,080	5,143	5,143
1920	117,419	18,641	20,335
1921	81,877	17,313	13,074
1922	157,558	32,401	1,792

Norwegian nitrate of lime is sent as far as California, Honolulu, Sumatra, Java, and Australasia, where it is preferred to other fertilisers. Chile nitrate is a potential source of alkali, and is undesirable in soils which already contain considerable quantitie of alkali.

When nitrate of lime gives up its nitrogen to plants it leaves lime in the soil which is beneficial. Mr. C. H. Smith, of San Francisco, writes me that for lemon and orange trees as much as three pounds of nitrate of lime is used per tree as a top dressing, and for sugar plantations in the Hawaiian Islands 500 to 1,000 pounds are used per acre.

AMMONIUM NITRATE.

A good deal of ammonium nitrate, NH_4NO_3, has been made by the Norwegian Hydro Electric Nitrogen Co., in fact, during the latter part of the war this was a principal output because the Allies wanted it for the burster charges for shells and mines. It is the most concentrated nitrogen compound on the market as it contains 35 per cent. half of which is in the form of ammonia-nitrogen and half as nitric nitrogen.

When used as fertiliser the ammonia acts slowly and the nitrate acts quickly, also it does not leave any compound in the soil as is the case with Chili nitrate and sulphate of ammonia.

It can be made in a non-deliquescent form, which keeps well in an open shed.

After the war a considerable amount of it was recovered from the amatol of burster charges, in shells, etc., and although it contained a small amount of T.N.T. it was used successfully as a fertiliser.

In America a considerable amount is used by horticulturists and I have seen a shipment of over 1,000 tons from Norway. If it pays to send that distance it ought to pay to make it there.

SPECIAL PRODUCTS.

Many valuable compounds can be made by means of the nitrogen dioxide gas of an arc furnace, for example, calcium arsenate $Ca_3(AsO_4)_2$. This is made by passing nitrogen dioxide gas through a solution of arsenious acid, which is run down absorption towers. The resulting arsenic acid is then treated with lime to form calcium arsenate.

Considerable quantities are used in the southern States of America for killing the boll-weevil—the insect pest of cotton plants. The method employed is for aeroplanes to go out soon after daybreak and fly low along the rows of cotton trees and dust them with the poison.

Mucic acid ($C_6H_{10}O_8$) can be made from galactose ($C_6H_{12}O_6$) which is a sugar extracted from a special kind of larch tree. The galactose solution is run down towers through which nitrogen dioxide gas passes and the sugar is oxidised, and some nitric acid formed with the water present. The result is a mixture of nitric acid and partially oxidised sugar from which the mucic acid can be crystallised out.

Mucic acid is valuable because it can be used instead of tartaric acid and citric acid for baking powders and for making jams and mineral waters, etc. It is also useful as a mordant for precipitating colour in the dyeing of wool, silk, cotton and leather. The world's consumption is said to be about 50,000 tons per annum.

GENERAL NOTES.

RECONSTRUCTION OF YOKOHAMA.—The British Chargé d'Affaires at Tokio reports that it has been definitely decided to reconstruct Yokohama as a port, the damage to the harbour works having proved less extensive than was originally feared. It is understood that Yokohama will remain the port of export of silk from Japan. The Commercial Attaché to the Japanese Embassy in London has informed the Department of Overseas Trade that repairing work is already in progress, and it is hoped that by the end of October ordinary port facilities will be re-established. At Kobé special arrangements have been made to deal with the congestion caused by diverting vessels to that port, and the situation is improving.

COTTON SPINDLES.—Great Britain's spindles on the 31st of July last numbered 56,583,000, or, roughly, 600,000 more than on the 1st March 1914, according to the *Manchester Guardian*. The United States came next with 37¼ millions, an increase of 5¾ millions; France third (through acquisitions in Alsace-Lorraine) with 9,600,000, an increase of 2,200,000; Germany fourth, with 9,605,077, a decrease of nearly two millions, lost to France, and India fifth, with 7,331,219, an increase of a little under a million. The rest were nowhere, apart from Russia's derelict spindles. It is true that Japan increased her total from 2,414,000 to 4,483,000, but part of the new supply was second-hand, and the increase is largely attributable to the fact that the Government of that country has undertaken to abolish night work as soon as it can, and it is necessary to obtain new machinery in the meantime to maintain the production. The world total at the end of July was a little under 156 millions, and 56¼ millions, or more than one-third, were in Great Britain. Our supremacy, indeed, does not stop there, for Lancashire makes considerably more fine goods than any other country, and these are the most profitable part of the trade.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH.—The Eighth Annual Report of the Department of Scientific and Industrial Research, which has just been published, gives an account of the work of the Department during the year ended 31st July, 1923. The report is divided into the following main sections:—Report of the Committee of Council. Report of the Advisory Council. Summary of the Work of the Research Boards and Committees of the Department. The Report is supplemented by appendices giving (1) particulars of the Research Boards and Committees of the Department, (2) statistics of grants made to individuals, (3) lists of aided researches, 1922-23, (4) a list of publications by individuals in receipt of grants, (5) an account of developments in the organisation of research in India, Egypt, and the Overseas Dominions, (6) information concerning Research Associations, (7) the enactment of the French Legislature and official decree relative to the establishment of the French Research Department, and (8) a list of Departmental publications. An index is added. Copies are obtainable at H.M. Stationery Office, price 4*s.* 2*d.*, post free.

PHOSPHATE PRODUCTION IN FRENCH OCEANIA.—The phosphate production of the colony of French Oceania, which is composed of the Society, Tuamotu, Marquesas, and scattered groups of islands, amounted to 60,000 tons in 1921. Shipments to the value of over £11,000 were sent during that year to Honolulu, the balance going to Europe. Exact figures of the 1922 phosphate output are not yet available, writes the United States Consul at Tahiti, but it has been conservatively estimated at between 80,000 and 90,000 tons. Material to the value of over £26,000 was shipped to Honolulu, the balance having been sent to Europe. The phosphate rock, as shipped, is said by company officers to run about 80 per cent. phosphate.

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No. 3,703. VOL. LXXI.

FRIDAY, NOVEMBER 9, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

NOTICE.

NEXT WEEK.

MONDAY, NOVEMBER 12th, at 8 p.m, (Cantor Lecture.) SAMUEL HENRY DAVIES, M.Sc., F.I.C., "The Cultivation of Cocoa in British Tropical Colonies." (Lecture I.)

WEDNESDAY, NOVEMBER 14th, at 8 p.m. EDOUARD BELIN, "Téléphotographie, Télautographie, Télévision" (avec Expériences et Projections.) ALAN A. CAMBPELL SWINTON, F.R.S., late Chairman of the Council, will preside.

Further particulars of the Society's meetings will be found at the end of this number.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

NITRATES AND AMMONIA FROM ATMOSPHERIC NITROGEN.

By E. KILBURN SCOTT, A.M.Inst.C.E., M.I.E.E.

LECTURE II.—*Delivered April 16th, 1923.*

FINANCIAL.

Table VII. gives the percentages of capital cost and operating cost of a typical arc process plant, without concentration and conversion plant.

The capital cost per ton of fixed nitrogen at the usual yields is about £140, and the operation expense, without electric power, is £20 per ton of fixed nitrogen per year. With 12 per cent. capital charges added to operating expenses the cost of dilute acid is about £37 per ton by fixed nitrogen. If the yield is taken at 7.3 k.w. years, per metric ton of fixed nitrogen, the power charges are about equal to all other charges for power at £5 per k.w.-year.

Table VIII. gives the costs of production per metric ton by nitric acid of 96 per cent. strength at the 8,000 k.w. arc plant at Pierrefitte, in France, which produced about 11 tons per day reckoned as 100 per cent. acid.

TABLE VIII.—*Cost of production of Nitric Acid of 96 per cent. strength.*

	£	s.	d.
Cost of power, estimated at 20s. per k.w.-year	2	0	0
Labour charges (say 20 men at 5s. per day)	0	10	0
Staff charges, etc.	0	10	0
Concentration costs	2	0	0
Extras	1	0	0
	£6	0	0

COMPARISON OF COSTS.

All the nitric acid made in this country is made from Chili nitrate by the old and wasteful Valentmer chemical process. Mr. Mason, a recognised English expert

TABLE VII.—*Percentages of Capital Cost and Operating Cost of an Arc Plant.*

Section of Plant.	Percentage of Capital cost.	Percentage of operating expenses.
Furnaces	23	35
Boilers and preheaters	8	7
Aluminium coolers	2	6.5
Oxidation tower	1.5	2
Acid absorption towers	35	15
Alkaline towers	8	15
Blowers	4.5	7
Miscellaneous	19	12

chemist, has published detailed figures which show that nitric acid of 65 per cent. strength and 1.4 sp. gr., is made for £20 a ton, when the Chile nitrate costs £13 per ton delivered at the retorts. That is after allowing for sale of the by-product nitre-cake, which is not always possible, for much of it is thrown away.

As a comparison, Mr. Hageman, formerly chief engineer of the Norwegian Hydro-Electric Nitrogen Company, published the cost of making nitric acid by the arc process as practised in Norway. Assuming the yield regularly obtained in Norway, namely, 540 kilograms of equivalent nitric acid per k.w. year, or 62 grams per k.w.-hour, he shows that it was possible to make nitric acid of 65 per cent. strength, sp. gr. 1.4, at £20 a ton with electric energy at £10 per k.w.-year. That is after deducting the value of nitrite of soda, which is the by-product, and sells readily for dye manufacture.

In Table IX. the figures are for a factory taking 10,000 k.w., and the yield of 540 kilograms of nitric acid per k.w.-year gives 6,250 tons of nitric acid 65 per cent. strength, and 825 tons of nitrite of soda 96 per cent. strength. The total manufacturing cost of £20 per ton of 65 per cent. nitric acid is made up as follows :—

acid with electric power at £10 a k.w.-year, assuming that the nitre-cake can be sold.

The price of Chile nitrate is governed by the Chile Nitrate Committee, and although nitrate has been sold a little lower, it has frequently been higher, so that £13 a ton may be considered as a fair price for nitrate delivered at the nitric acid factory.

On the other hand the figure of £10 per k.w.-year for electric energy is high because the report of the Nitrogen Products Committee gave £3 15s. per k.w.-year as a possible figure for energy from an English power station using coal in ordinary way. For all the hours of the year £10 is about ¼d. per k.w.-hour, and that is too high for off-peak power, the utilisation of which has the effect of evening up the load on a large power house and so reducing the proportion of establishment charges per unit.

MANUFACTURE IN GREAT BRITAIN.

I always visualise the making of nitrates from air as an Empire matter, and there are in the Dominions many water powers which can be harnessed as cheaply as those in Norway. Some people, however, seem to be only able to think in terms of this country, so it may be of interest to consider the possibilities here.

Estimates by the hydro-electric department of Armstrong, Whitworth and Co. show that a certain Scottish water power can be harnessed to sell electricity at £4 per k.w. year. This is more than in Norway but there are the compensating values to make up for extra cost of power.

TABLE. IX.—*Cost of making Nitric Acid by arc process.*

	Total. £	Per ton of 65 per cent. nitric acid. £ s. d.
Materials, soda, etc.	10,000	1 12 0
Administration wages, etc.	30,000	4 16 0
Upkeep, repairs to furnace, etc.	8,750	1 8 0
Sundries, stores, oil, etc.	4,250	14 0
	53,000	8 10 0
Cost of energy: 10,000 k.w. at £10	100,000	16 0 0
	153,000	24 10 0
Deduct 800 tons nitrite of soda at £35	28,000	4 10 0
	125,000	20 0 0

Such a factory will cost £162,500, equal to £26 per ton of 65 per cent. nitric acid, or say £150 per ton of fixed nitrogen.

From the above it will be seen that to make nitric acid from Chile nitrate at £13 a ton is equivalent to making similar

The first is that by manufacturing here there would be less cost for freight of raw materials and products. The Rjukan I. and II. plants of the Norwegian Hydro-Electric Nitrogen Co. are 90 miles from the port of Skien, and up on the mountains. Before the products get to port they have to pass over three different systems of transport, including lake steamers, and there are half-a-dozen handlings. When ammonium nitrate is made with ammonia liquor sent from this country there are heavy freight charges in carrying the ammonia and water in containing tanks to Norway.

The amount saved in carriage and handling is available for paying for higher priced electric energy here, but independently of that it ought to be done from the point of view of continuity of supply in difficult times and as a national insurance. It would be an advantage to harness any water power now running to waste and make the plant for it. The present 300,000 k.w. of plant in Norway has given employment to very many people and profitable work to many firms, and this again has enabled the firms to launch out into other business and employ still more people. The creation of a new industry is one of the finest pieces of public service that anyone can do and I have the greatest admiration for those young engineers who established the arc process on so sound a footing in Norway.

Norwegian Hydro-Electric Nitrogen Company.

Table X. gives the exports in metric tons by the Company and although it will be noted that there was a drop in export of nitrate of lime in 1921, it has been more than made up in 1922, the figure being nearly double. The export of sodium nitrate has nearly doubled, and this is very significant for a year when those in the Chile nitrate trade have used every endeavour to get business. Nitrate of soda made by the arc process is much purer than the best refined Chile nitrate.

The Norwegian Company has paid handsomely from the commencement, and for the past three years dividends have been at the rate of 15 per cent. on a capitalisation of 55,000,000 kronen, which, at normal exchange, is about £3,000,000. Enormous sums have been set aside for amortisation and reserve, in fact, a great deal of the cost of the plant has been written off.

The hydro electric power companies are financed separately from the nitrate plants and they pay 20 per cent. dividend.

The company gives 2 million kronen per annum as bonuses to staff employees and workmen, and a very considerable amount is also distributed as fees to directors, managers, and secretaries, etc.

Another special feature of this extraordinary concern is the magnificence of the power houses and office buildings. The accounts show that 4 million kronen have been allocated to a new office building in Christiania.

The Company's financial and technical success has been consistently unique ever since it started operations with a 500 k.w. plant, about 17 years ago. It now operates about 300,000 k.w. of plant, and does not require to use propaganda to sell the products.*

ELECTRIC POWER.

Although most of the arc process plants are run with electric energy obtained from waterfalls, it is a mistake to suppose that water power is essential. For an output of, say, 50,000 k.w. a steam electric station may be assumed to cost £10 per k.w., and it can be built in well under a year. On the other hand a hydro-electric station, using a medium head fall may cost £30 a k.w., and

* See article on Nitrogen Fixation of the Arc Process Financial Results of the Norwegian Company by E. K. S., *"Chemical Trade Journal and Chemical Engineer," October 6th*, 1922.

Table X.—*Exports of Arc process products from Norway.*

	1919	1920	1921	1922
Sodium nitrate	5,143	18,641	17,313	32,400
Nitrate of Lime	63,080	117,419	81,877	157,558
Nitric acid (concentrated)	1,430	1,233	794	1,116
Sodium nitrite	1,887	7,238	1,619	1,674
Ammonium nitrate	5,143	20,335	13,074	1,792

take several years to build, because of the dams, water races, pipe lines, etc.

Of course, when it is built a steam electric station has to be kept going by a considerable expenditure on coal and water. The hydro electric station is supposed to get its water free but that is not always so, for there may be charges for taking over water rights and compensation paid for submerging lands, etc.

from air lends itself in an absolutely ideal way to the favourable utilisation of off-peak power. The furnaces can be switched on and off like large arc lamps, and they give full yields within a few minutes of starting up. The suitability of arc plants for working with off-peak power has been amply proved by actual experience, at Legnano in Italy; Seattle, U.S.A.; Pierrefitte in France, etc.

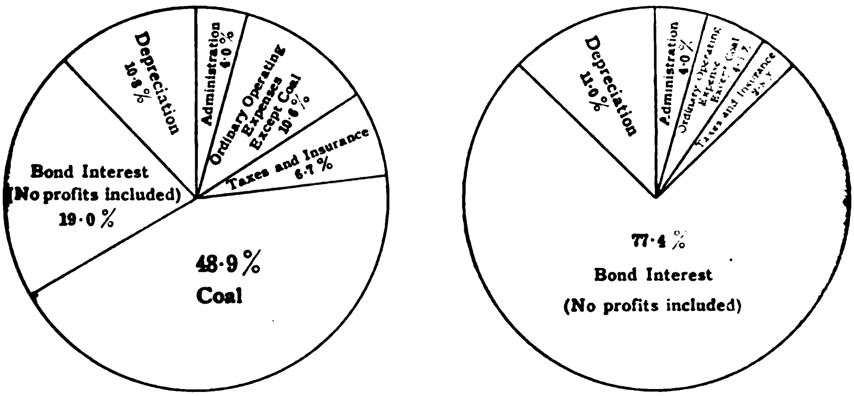

FIG. 11.—Finance of Steam and Hydro-Electric Power Stations.

These diagrams show at a glance the difference in the finance of two types of power stations. The building of the steam station is principally a matter of good engineering, so as to ensure that a minimum of coal shall be burnt for a given amount of power generated. The largest sector of the first circle, therefore, represents coal. On the other hand with a hydro-electric station the largest sector represents interest on money spent on dams and hydraulic works, etc. It also includes a considerable amount of interest on capital for the much longer period that it takes to build such a station.

In Fig. 11 the first circle shows coal as the largest sector, whereas interest and sinking fund charges form the largest sector of the second diagram. This shows that the principal problem of generating power in a steam station is one of good engineering, whereas the principal factor in a water power station is financial.

The cost of hydro-electric power depends primarily on the rate at which very large sums of money can be borrowed.

OFF-PEAK POWER.

I believe that the super steam power stations now being built will be able to sell energy during off-peak hours at figures which will compare favourably with the cost of energy from water power stations, especially when all the circumstances of convenience of working and carriage of products to markets, etc., are taken into account.

It cannot be too strongly emphasised that the arc process for making nitrates

Towards the end of the war the United States Government had decided to build arc plants to off-peak power. Mr. Liljenroth, of the Du Pont Co., and formerly consulting engineer to the Norwegian Hydroelectric Saltpetre Co., was employed to get out plans for the purpose.

At the Rynkan II. plant in Norway there are three 4000-k.w. steam turbo-alternators supplied with steam from boilers heated by the hot furnace gases, and it is very significant that in an installation having practically unlimited water power, steam turbines should have been installed to regenerate some of the energy and pass it back into the furnaces.

Ten per cent. of the total can be returned in this way, and this is a point in favour of establishing an air nitrate factory in conjunction with a super steam power house.

NEW DEVELOPMENTS.

The Norwegian Hydro-Electric Nitrogen Co. is replacing some of the plant which

has done good service for 15 years, and the new developments will epitomise all the research which their engineers have been doing.

The Nitrum Company of Switzerland has made a very real advance in the art by doubling the concentration of nitrogen oxide, and by liquefying the nitrogen dioxide gas at low temperature.

Canada is moving strongly in the direction of the arc process. The American Company, which has been operating Wiegolofsky furnaces at Seattle for making sodium nitrite, has built a plant at Lake Buntsen in British Columbia, and this is now running continuously with a force of 35 men. The plant is to be greatly extended.

The Electro Chemical Co., Canada, is going to build an arc plant near the large new power house at the Niagara Rapids, fed with water from the Chippeawa Canal.

Its contiguity to a large plant which will be able to give a great deal of off-peak power at a low cost is promising.

There is considerable significance in the news that Mr. J. B. Duke and his associates are to proceed energetically with the harnessing of the Sagueney River power in Canada. A principal object of this is to make fertilisers. When fully harnessed it will be larger than Niagara power.

Countries with small populations, but having large water power, show considerable interest in the matter, as for example, some of the South American Republics; also in New Zealand, thanks to Mr. J. Orchiston, late chief electrical engineer to the Government, there is a movement to use a fine water power in Milford Sound.

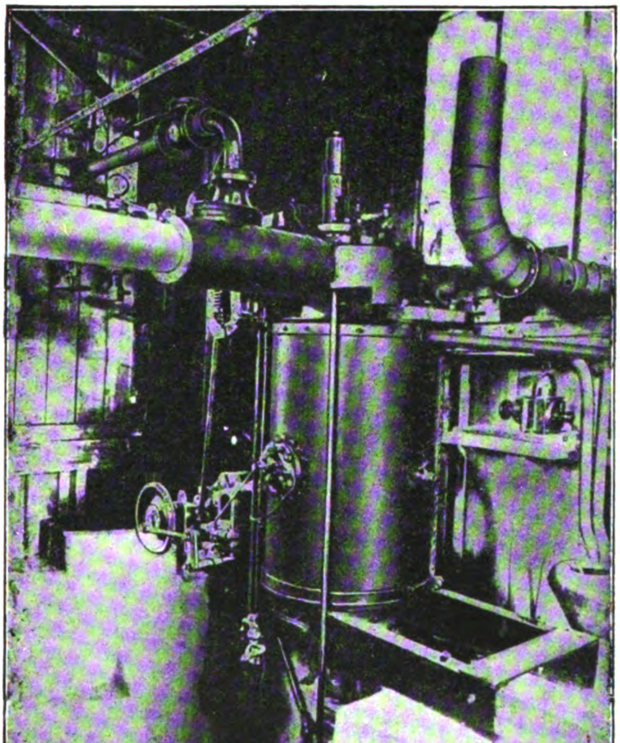

FIG. 12.—Steel Bomb of the Hausser Process, showing the Sparking Device.

Coke oven gas from which the hydrogen has been removed is mixed with air and exploded in the bomb by the spark from a magneto. There are about 45 explosions per minute and after each one the bomb is scavenged with air. The resulting nitrogen oxides have a concentration slightly under one per cent, and after cooling down are absorbed by water to form dilute nitric acid.

EXPLOSION PROCESS.

The Hausser process* produces nitrogen oxides by the explosion of gases in a specially-constructed bomb. Hausser's first experimental plant consisted of a bomb of 100 litres capacity which gave 10 ignitions per minute, with coal gas, and delivered an exhaust containing 9 grammes of nitric acid per cub. metre.

A second plant (see Fig. 12) erected at a battery of coke ovens in Westphalia consumed 5,000 cub. metre of coke-oven gas per 24 hours, having about 3,800 heat units per cub. metre. The gas freed from sulphur was forced into a bomb by a compressor along with air preheated to 300° C. in a tube by the exhaust gases. The gas and air are compressed to 6.0 kg. per sq. c/m., and the bomb scavenged with air at 0.75 kg. per sq. c/m.

Each bomb gave 45 explosions per minute and the exhaust valve opened .15 sec. after the explosions. The pressure rises to 25 kg. per sq. c/m. After the exhaust the combustion gases are scavenged and the exhaust and air valves closed, the sequence begins again.

The concentration of the gases is under one per cent. and the gases are treated in the same way as those of the arc process. They pass through a marine boiler to raise steam, then through aluminium tubes immersed in water to reduce the temperature to 50°C.

There is an oxidation chamber, five acid scrubbing towers and two towers of sheet iron, in which the residual oxides of nitrogen are treated with soda solution for the production of nitrate.

The gas contains about 12 g. of nitric acid per cb. m., and this is converted into 28 per cent. nitric acid with an exit loss of 3 g. of nitric acid per cb. m. The soda towers yield a 24 per cent. solution of sodium nitrate containing 8 per cent. sodium nitrate and some bicarbonate.

High Pressure Absorption.

As a result of experience with the above plants, the inventor has lately designed one which employs bombs of 1,000 litres each. He also absorbs the gas at a pressure of three atmospheres, because the size of the towers is thus much reduced. The pressure is easily maintained by the bombs, and no other fixation of nitrogen process offers such easy facilities for using pressure. The absorption towers must, of course, be capable of withstanding pressure and acid, and for this chrome nickel steel is suitable.

In his paper Mr. F. Hausser gives figures to show that when absorption is carried on at three atmospheres the tower capacity can be cut down in size to about a fiftieth of what is required at ordinary pressure.

One advantage of the Hausser explosion process is that it can be carried out in small units, thus a plant to make 17½ tons (reckoned as 100 per cent. nitric acid) per 24 hours would, on the pre-war basis, cost about £75,000. The whole of the power requirements can be covered by heat and power regenerated from the combustion of the coke oven gases. The yield and concentration are expected to be much higher.

On a pre-war basis the cost of operation is about £75 per day, including the value of the gas at £3 10s. per thousand cub. metres. The cost per ton of nitric acid, reckoned at 100 per cent., exclusive of concentration costs, works out at £4 5s.

Effect of Hydrogen.

Mr. T. Twynam, of Middlesbrough, has noted that in the exhaust of large coke oven gas engines there is a considerable quantity of nitrogen-oxides, whereas the exhaust from blast furnace gas engines has very little.

As a result of his observations and tests, he has worked out a novel method of extracting the nitrogen oxide gases from the exhaust of engines which use coke oven gas.

It has been known for some time that by removing the hydrogen from coke oven gas the net calorific value is increased about 50 per cent. The yields of the explosion process can be thus increased. Mr. C. J. Goodwin is working on the new development.

Prof. Bone, F.R.S., and his associates have investigated the action of hydrogen in gas explosions in a careful academic way and have found out some very interesting facts, which are stated in a recent paper* before the Royal Society.

* See Technical Synthesis of Nitric Acid by means of Gaseous Explosions, by F. Hausser. *Journal of the Society of Chemical Industry*, June 30th, 1922, Vol. XLV., No. 12, pp. 253R-259R.

* See Gaseous Combustion at High Pressure, Part III. The energy absorbing Function and Activation of Nitrogen in the Combustion of Carbon Monoxide, by Prof. W. A. Bone, F.R.S., D. M. Newitt, B.Sc., and D. T. A. Townend, B.Sc. Proceedings of the Royal Society, A. Vol. 103, 1923.

The following is an extract :—

Nitrogen can no longer be considered as an inert gas in the combustion of carbon monoxide because when added as a diluent to a mixture $2CO + O_2$ undergoing combustion under such high pressure as has been employed in our experiments, it exerts a peculiar energy absorbing influence upon the system, far beyond that of other diatomic diluents or of Argon. * * * It seems as though there is some constitutional correspondence between CO and N_2 molecules (whose densities are identical), whereby the vibrational energy (radiation) emitted when the one burns is of such a quality as can be readily absorbed by the other, the two thus acting in resonance. The pressure of hydrogen in a $2CO + O_2 + 4N_2$ mixture undergoing combustion so strongly counteracts the aforesaid "energy absorbing" influence of the nitrogen that, as far as possible, hydrogen must be excluded from the system if any large nitrogen effect is to be obtained.

Humphrey Free Piston Engine.

The work done by the explosion in the Hausser process is thrown away, and this fact caused Mr. H. A. Humphrey to investigate the possibilities of applying the principle of his loose piston explosion pump. He made a working design in 1917, which is shown in Fig. 13, and the action of which is as follows:—

Imagine the piston G at the end of its stroke to the left and behind it compressed charge of gas and air which is ignited by an electric spark. The valve 1 being shut the piston G is driven at very high pressure and great velocity to the right, and the gases expand until the left-hand end of piston G reaches port 3, and this being a large one the pressure falls rapidly and the exhaust gases pass downward through the tubular reheater EF. These exhaust gases contain the nitric oxide gas and they pass to the absorption apparatus, where the nitric oxide is contacted with water to make nitric acid.

As soon as the pressure has fallen sufficiently, scavenging air stored under slight pressure in pipe 11 and between valves 1 to 8 opens valve 1 thus sweeping the gases towards port 3. The piston then completes its travel to the right.

When the piston commences its stroke towards the left, air is compressed in chamber or cylinder C and is delivered past valve 8 through the top half of the reheater E into chamber or cylinder A. A little later a rich gas mixture from B now under some pressure is forced through port 5 and valve 2 to mix with the hot air in chamber A. The piston in its movement to the left closes port 3 and compresses the explosive mixture, the electric ignition at the right moment then starts a fresh cycle as above.

Now consider cylinder B. The piston in travelling to the right takes in a rich gas mixture, and on its return stroke to the left acts as a pump and forces the mixture through port 5 and valve 2 into chamber A. The exact pressure at which valve 2 is opened is determined by an adjustable spring on this valve. When port 3 is closed by piston G as the length of the remaining space B is greater than the remaining space in A, the

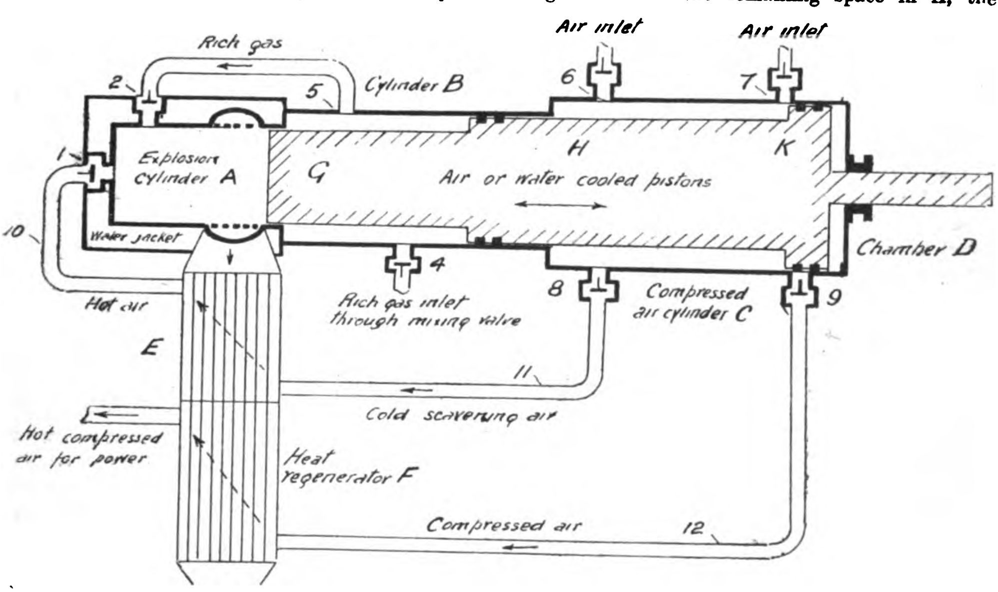

Fig 13.—Humphrey Free Piston Engine for Fixing Nitrogen.

Design due to H. A. Humphrey, which combines the explosion process for making nitric oxide with an engine to compress air for power purposes. The piston is free, and so can move at various speeds to suit the explosions, etc.

pressure in A rises faster than in B and valve 2 closes. Chamber C is an ordinary air pump, and while the piston is travelling to the right, air is drawn into the annular space C past the non-return valve 6. When the piston travels to the left this air is delivered past the valve 8 through the reheater E into chamber A so long as port 3 is open.

When port 3 closes the pressure in A rises more quickly (due to the ratio of clearance spaces) than the pressure in C, and, therefore, valve 1 immediately closes and the only effect of the piston travelling to the left is to store air under some pressure in the pipe system between valves 8 and 1.

Turn now to the operation in chamber D. When the piston moves to the right, air is compressed and then delivered past the non-return valve 9 to the air pressure storage vessel This delivery is cut off when the piston closes port 9, and from this point the air is further compressed into the closed space at the end of D until the kinetic energy of the moving piston is absorbed in raising the pressure of the enclosed air, thus bringing the piston to rest. The energy in this compressed air starts the piston in its movement to the left again and imparts momentum to it until air in D has expanded to atmospheric pressure. From this point the further travel of the piston draws in fresh air through inlet 7 for the rest of the stroke.

The acceleration of the piston when first moving to the right is very great, owing to its being a free piston, and the gases are at great pressure. Expansion is, therefore, more rapid than is possible in a gas engine, when the piston travel must conform to the movement of crank and flywheel. The slowest movement occurs towards the end of travel to the right, and this gives time for the scavenging gases to pass through at low pressure.

Electrical ignition is by means of a contact device placed in the cylinder which is cold. It consists of an adjustable stationary contact attached to the wall of cylinder C and a moving contact attached to piston K.

The electric spark is produced in A somewhat before the end of the stroke, thus giving the maximum possible explosion temperature. When the gases are preheated before compression ignition (and pre-ignition) may become spontaneous.

CYANAMID PROCESS.

The calcium cyanamid process is due to the work of Drs. Frank and Caro, who followed up some researches of Profs. Playfair and Brunsen. They were trying to make cyanamid of potassium and stumbled on the fact that calcium carbide would absorb nitrogen to form cyanamid and that when the latter was treated with steam it gave off ammonia.

In a paper read before this Society on May 15th, 1912, I described the cyanamid works at Odda in Norway, and gave a sketch of the electric ovens then used for changing the carbide to cyanamid. Since then many factories have been built. The largest is at Mussels Shoals in Alabama, U.S.A., and I propose to give a full description, as I happen to have visited the plant.

In 1917 the Ordnance Department asked the American Cyanamid Company to organise a subsidiary concern known as the Air Nitrates Corporation, to act as agent of the Government for the construction and operation of cyanamid plant at Mussels Shoals to make 300 tons of ammonia nitrate per day. The plant was to be operated at a fee of one cent. per lb. of ammonia nitrate until the 1st of June, 1921.

Westinghouse, Church, Kerr Co. erected the buildings, the camp and permanent city. The J. G. White Engineering Corporation designed and built the carbide furnaces and cyanamid ovens, etc. M. W. Kellogg and Co. made the piping and built the chimneys. The electric power station, built by the J. G. White Corporation, contains a 60,000 kw. Westinghouse steam turbo generator. In eight months and eight days the plant was ready to begin producing ammonium nitrate. In four months 12,000 workmen were on the job, and within eight months a city capable of accommodating 25,000 inhabitants was built complete with restaurants, stores, offices, police headquarters, schools, fire department, hospital and picture theatre.

The sizes of the principal buildings are as follows, and their names also serve to show their sequence.

Building.	Size in feet.
Carbide furnace	1050 x 90 x 55
Carbide cooling shed	950 x 50 x 40
Carbide grinding	150 x 120 x 57
Cyanamid ovens	520 x 250 x 42
Cyanamid grinding	150 x 120 x 57
Liquid air	578 x 103 x 46
Hydrating	83 x 53 x 51
Machine shop	382 x 103 x 23
Autoclaves	253 x 61 x 67
Oxidation tower	600 x 100 x 26
Absorption towers	600 x 100 x 91
Catalysers	212 x 51 x 23
Electrical distribution	160 x 50 x 43
Neutraliser	152 x 93 x 33
Ammonium nitrate	122 x 62 x 37

Carbide Furnaces.

Fig. 14 shows the flow sheet for the making of (1) calcium carbide, (2) pure nitrogen from liquid air, (3) calcium cyanamid, (4) ammonia from the cyanamid, (5) catalytic conversion of half the ammonia, (6) com-

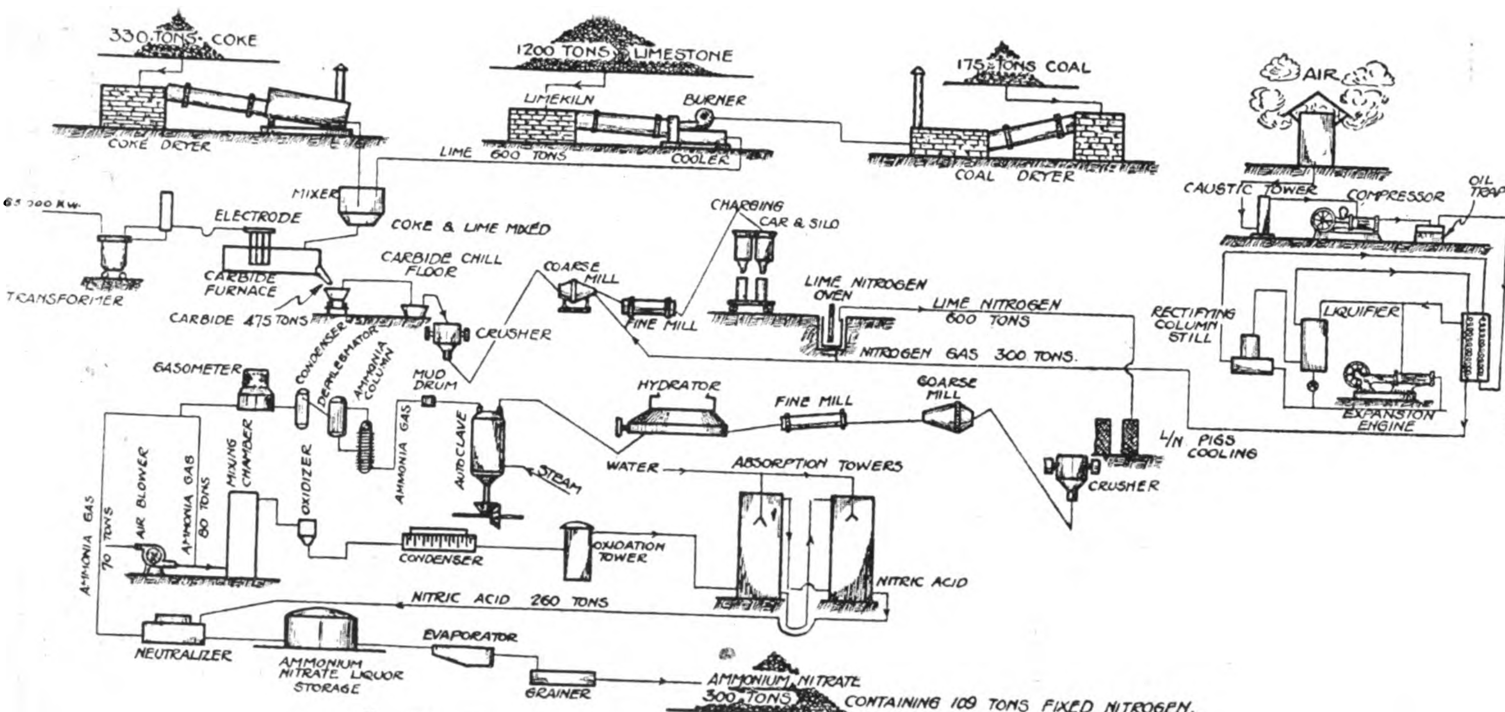

FIG 14.—Flow Sheet of Cyanamid Process at Mussel Shoals, Ala., U.S.A.

The figures give the daily quantities of raw materials for a daily production of 300 tons of ammonia nitrate. Power required for the carbide furnaces is given, but not that for the lime nitrogen ovens, steam boilers for autocloves, and motors for driving various machines, ets.

bining of the nitric acid with the other half of the ammonia.

The calcium of carbide electric furnaces are twelve in number, rectangular in shape, 12ft. by 22ft. by 6ft. deep inside, made of steel and lined with firebrick. They use three-phase electric energy at a pressure of 130 volts., stepped down from 12,000 volts. by transformers of 8,325 kw. capacity. When operating normally the current is 20,000 amp., and the output per furnace is 50 tons per day for 24 hours.

The electrodes are carbon blocks 16in. square by 6ft. 5in. long. With a portion an area is planed at each side of one end so that a copper head can make good electrical contact. It is secured by special bolts to three of the blocks fastened together as one electrode. They are covered by wire netting and a protecting layer of asbestos and retort cement which is baked on in an electric furnace.

One complete electrode with its copper head weighs about 3½ tons, and the carbon is consumed at the rate of 70 lb. per ton of carbide. Three of the complete electrodes are suspended from arms over the top of the furnace, and the immersion of the ends of the electrodes in the molten bath is controlled electrically.

The copper bus-bars of each electrode are 5/16th in. by 8in. wide, and there are 16 bars to each. The bottom of each furnace is made of graphite electrodes, 16in. square by 48in. long, set in a layer of tar and gravel. To start the furnace, a quantity of crushed coke is thrown on the bottom, and the electrodes lowered on to it. The proportions of the charge are 1,000 lb. of quicklime and 600 lb. of dried crushed coke.

During the tests it was found that the first tap could be made six hours after starting, and thereafter the furnace tapped every 45 minutes. The furnace is kept full to the top by shovelling the mixture by hand as required. A few shovels-ful of powdered carbide thrown into the tapping hole will stop the outflowing mass.

Crushing Plant.

A railway line and electric battery locomotive transports the cars containing the hot carbide to the carbide-cooling buildings, and as contact with water produces acetylene, care is taken completely to protect the carbide from rain and snow. The buckets containing the carbide pigs are picked off the cars by a travelling crane and set aside to cool, and then dumped on to the crusher platform.

Three 36in. by 42in. crushers break down the carbide to about 1¼ in. size which go to Hardinge ball mills for grinding so that 80 per cent. will pass through a 40-mesh screen and the balance through a 10-mesh screen. Finally, three tube mills pulverise the carbide until 85 per cent. will pass through a 200-mesh screen.

All the grinding must be done in an atmosphere of nitrogen, this inert gas being piped from the liquid air building.

Pure Nitrogen.

Pure nitrogen is made by the liquid air process, and as it is important to have clean air two 36in. pipes extend north and south for 1,600ft. for the sake of getting a pure supply. The air is forced through sets of scrubbing towers 8ft. in diameter and 30ft. high packed with 6in. spiral rings fed with a fresh solution of caustic soda for each tower. This is to remove impurities, chiefly the 0.04 per cent. of carbon dioxide, which would give trouble in the subsequent operation of freezing. The caustic soda liquor discharged from the scrubbers goes to the ammonia gas department, where the carbonate is removed and the caustic solution made up to the strength again.

The Claude process is used and the plant consists of 15 twin-duplex pumps compressing air to 600lb. in three stages: 30lb., 140lb. and 600lb. There are 30 nitrogen columns, six being spare, which are oval in shape, 24 ft. high. Each column has many superimposed horizontal trays, each about 1½in. deep, on which the liquid rests through which the rising gas must bubble.

The compressed air is allowed to expand from 600lb. to 50lb., and in doing so it operates a small engine which generates thereby about 5 h.p. The air at 50lb. pressure enters the rectifier, and at this stage is below the critical temperature of air, namely, −140 deg. C. About one-tenth of the air at 600lb. is admitted to the rectifier, and the increased pressure on the cold air at 50lb. pressure liquefies the air. The oxygen of the liquid air begins to distil off at —182 deg. C. and the nitrogen at —195 deg. C. The oxygen, therefore, tends to remain liquid, whilst the nitrogen goes over into the gaseous state.

A liquid rich in oxygen about 50 per cent.

forms at the bottom of the rectifier and the gas in the rectifier gradually becomes richer in nitrogen as it approaches the top. At the top of the rectifier the gas is sprayed with liquid nitrogen, and the gaseous nitrogen, 99.9 per cent pure, escapes at a pressure of 10 inches of water. Each nitrogen column produces nitrogen at the rate of 500 Cu. metres (1,765 cu. ft.) per hour. The oxygen passes through a heat-exchanger and is allowed to escape.

Fig. 15 shows a Linde liquid air plant which is somewhat different from the above. It was used at the cyanamid factory at Odda in Norway.

Cyanamid Ovens.

For the manufacture of the calcium cyanamid there are sixteen rows of electric ovens, with 96 in a row, thus making 1,536 ovens in all, each 4ft. 4in. outside diameter, 2ft. 10in. inside by 5ft. 4in. high. It is of sheet steel with a 9in. lining

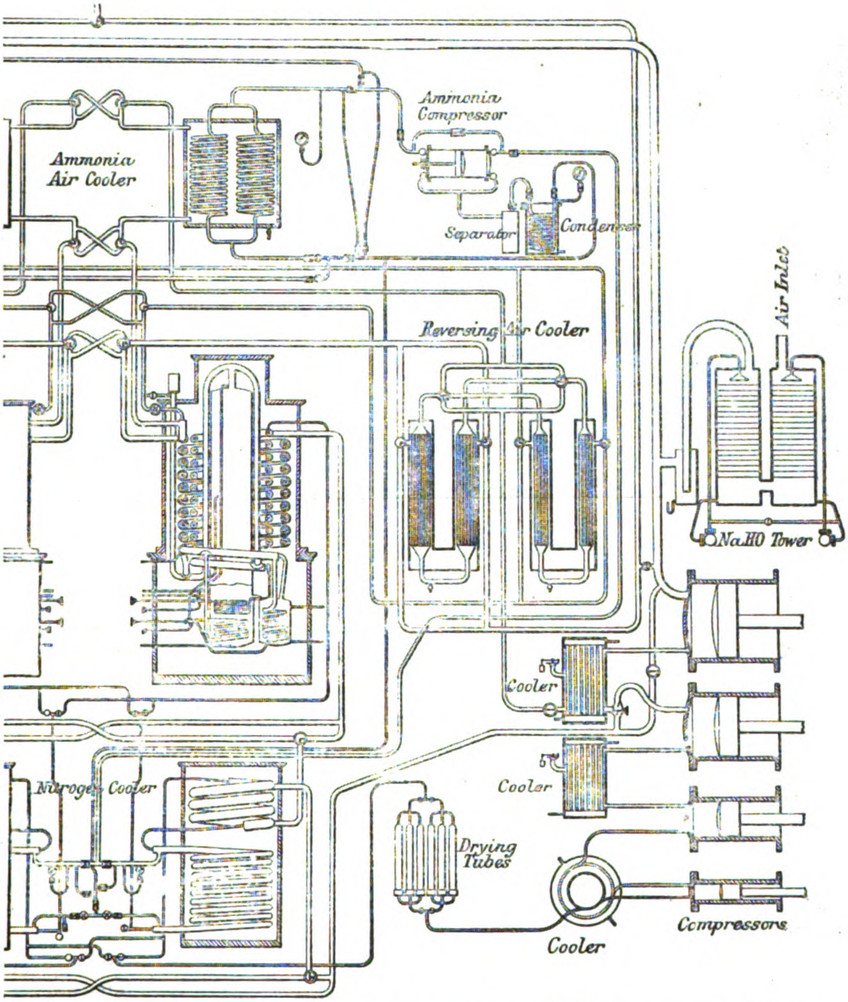

Fig. 15.—Linde Plant for Extracting Nitrogen and Oxygen from the Air.

This figure shows one-half of a liquid air plant, the other being a duplicate. The nitrogen comes off at a slightly different temperature and so can be isolated in a pure state from the oxygen. In cyanamid plants the oxygen is thrown away, but if an arc process was working near then that oxygen could be used for enriching the air to the furnaces.

of firebricks. A cylindrical paper container 2ft. 6in. in diameter, and a central vertical paper tube 3in. in diameter are inserted in the cold oven, and a charge of about 1,600 lb. of pulverised carbide is run in. The annular space of 2in. left between the paper container and the brick lining of the oven is required for lifting out the cyanamid pig. The two covers are luted for sand.

Fig. 16 shows a number of such ovens.

cyanamide contracts considerably, and after the process is finished it is removed by two spoon-shaped grabs, which are lowered by the crane.

After the pigs of cyanamide have been conveyed to the cooling room they are broken up and the cyanamide pulverised by machines similar to those used for the carbide. The cyanamide is pulverised so that 95 per cent. will pass through a 200-mesh screen and all grinding and pulverising

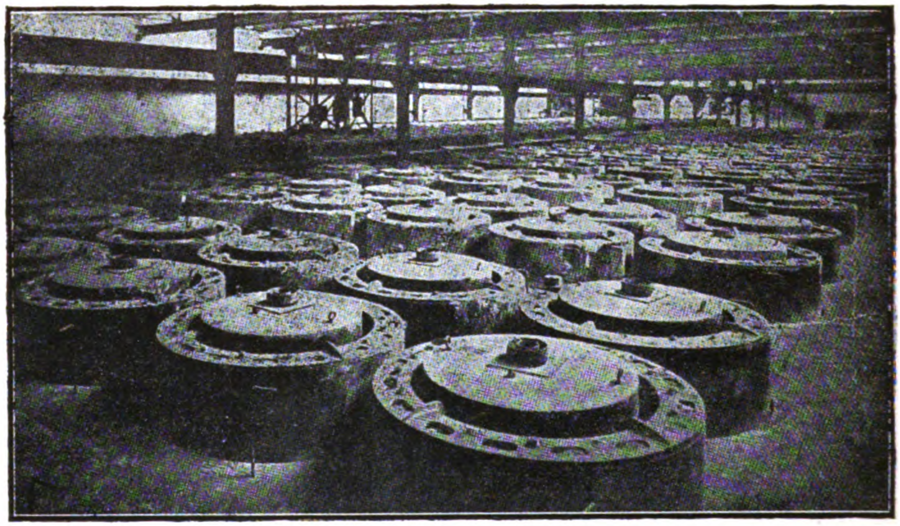

FIG 16.—Electric Ovens for Converting Calcium Carbide into Calcium Cyanamid.

The powdered carbide is fed into a papier maché container in the oven, a hole being left down the centre by a tube of the same material. After the lids have been put on a carbon rod is lowered down the centre and the heating up of the rod by electricity starts the combination of the carbide with pure nitrogen gas, which is fed in.

Nitrogen is brought to the furnaces by 8in. spiral riveted pipes and from these 1½in. pipes run to the centre, and to the side near to the bottom. Each pipe is provided with a valve. A carbon pencil ⅞in. diameter and 6ft. 6in. long, is inserted inside the paper tube, and it is supplied with single-phase current as follows :—100 volts and 200 to 250 amp. for 20 minutes, and 50 volts and 100 to 115 amp. for 12 hours.

The reaction continues for 40 hours longer. At a temperature of about 2,000° F. the material sinters together to form a solid pig. Of course, when the electricity is turned on, the papier-maché tubes burn away, but they last long enough for the material to hold up until the particles begin to sinter. The hard dense pig of

is again done in an atmosphere of nitrogen. The milled cyanamide is conveyed by screw conveyors to an elevator and thence by a regulated hopper feeding device, to three hydration troughs each 36ft. long, 3ft. in diameter, open top, and containing a horizontal revolving shaft with projecting wings.

Water, in amount proportional to the free carbide in the cyanamide as shown by chemical analysis, is sprayed in at the feeding end of the trough and the material is conveyed by the revolving agitator to the other end, by which time it is dry. The agitator revolves at 50 r.p.m. and conveys the material along the trough at 50ft. per second. The liberated acetylene goes to waste.

Autoclaves.

There are 56 steel autoclaves for the manufacture of ammonia from cyanamide. Each is a cylindrical steel tank, 8ft. in diameter and 20ft. high, and 1¼ inch thick, provided with a vertical agitator, which revolves at 12 r.p.m. during the whole reaction period.

Before charging the cyanamide into the autoclave, a 2 per cent. solution of caustic soda is run in to a depth of 9ft. and about 300lb. of soda ash is added. Since the cyanamide carries about 13 per cent. of free lime, the latter reacts with the soda ash to form some additional caustic soda, thus making the solution equivalent to 3 per cent. in strength.

The charge of cyanamide is 8,000lb., and as it leaves the hydration building, with about 2 per cent. of undecomposed calcium carbide, the first reaction in the autoclave is acetylene gas, and this is allowed to escape.

After all the acetylene has passed off the valve is shut and steam at 150lb., pressure is admitted for 20 minutes, when ammonia begins to form in the autoclave, the reaction being exothermic. The steam is supplied by four 825 h.p. Stirling boilers.

When the pressure in the autoclave rises to 250lb., the ammonia valve is opened cautiously, and the pressure maintained constant for three hours. After this the pressure begins to fall off. The valve is then closed again and steam is admitted a second time for 20 minutes and the reaction continued, this time at 200lb. pressure, for 1½ hours.

The chemical reaction in the autoclave is $CaCN+2H_2O=CaCO_3+2NH_3$. The pressure must not rise so high as to cause loss of ammonia through the safety valves. The gas escaping from the autoclaves is about 25 per cent. ammonia and 75 per cent. steam.

After the cyanamide has been acted upon a sludge is left behind which consists of carbonate of lime, caustic soda and free carbon. This is blown out through an 8in. outlet at the bottom of the autoclave by steam. It flows by gravity to the filter room (150ft. by 160ft.) adjoining the autoclave building, where it is treated for the recovery of caustic soda. In the filter room there are two sets of Oliver rotary filters, ten filters to a set. Each of the four sludge troughs feeds into five filters which operate under a suction of 20in. of mercury, produced by three vacuum pumps.

Ammonia Columns.

The ammonia gas from the autoclaves goes through columns about 10ft. in diameter and 25ft. high, each containing 16 horizontal plates. The gas enters at the bottom, and rising through 4in. holes in the plates, covered with bell-shaped caps, bubbles through ammonia liquor standing on the plates or shelves. It then goes into seven sets of condensers having two connected in series to each set. These contain vertical tubes through which water circulates, and the steam is condensed.

The gas then goes to a 28in. pipe, which is tapped by two 60,000 cu. ft. receivers. One supplies the catalyzer plant for converting some of the ammonia to nitric acid, while the other carries 45 per cent. of the ammonia gas to the neutralizer building.

It was intended to make ammonia nitrate by converting half the ammonia into nitric acid and combining it with the rest of the ammonia.

Platinum Catalysers.

Ammonia gas from the receiving tanks is mixed with air in the proportion of one to nine in 12 steel mixing tanks (8ft. in diameter by 30ft. high), which are filled with 6in. spiral rings.

The catalyser building has 696 catalysers. The ammonia gas enters at the top through an iron pipe flanged to the aluminium casing, which is a rectangular box 14in. by 28in. by 5ft. high. At the base of the aluminium box there is a sheet of platinum gauze suspended horizontally. This gauze is made of 3/1,000in. platinum wire, and has 80 meshes to the inch, and each sheet weighs 4.6 ounces troy.

Single-phase current from an 8 kw. transformer at 21 volts, and 375 amperes heats the platinum gauze to 750° C. The incandescent platinum gauze can be seen through a small window in one side of the aluminium box. The ammonia and air passing through the platinum gauze catalyst is converted into nitric oxide, which passes through a cast-iron pipe at the bottom of the catalyser to a flue or tunnel made of concrete and lined with chemical brick laid in acid-proof cement. These tunnels convey the oxides of nitrogen to 24 coolers.

The first coolers are merely horizontal boilers and the gases passing through

them are cooled from 600° to 200° C. They then pass through aluminium pipes 30in. dia. to 12 low temperature coolers, each of which consists of a rectangular chamber, divided into five compartments by four walls which do not reach entirely across the width of the chamber, so the gas is caused to take a zigzag course. Suspended from the top there are 140 tubes 5in. dia, and 7ft. long. In two of the compartments the tubes are made of chemical stoneware, and in the others of Duriron. Each tube is provided with an outlet lip at the top and inside each is an inner tube, down which water flows. It rises in the outer tube and escapes at the lip. The gas is cooled to 30° C.

Any nitric acid which formed in these low temperature coolers is drained into No. 3 well of the absorption tower system.

Absorption Towers.

There are twelve oxidation towers, each 15 feet square, and built of chemical brick. Each tower is divided by two walls into four equal compartments, and the gas passes up one compartment, over the top of the dividing wall, down the next, through a hole at the bottom of the wall, up the next compartment, over the wall, and down the last compartment. The gas is now practically all N_2O_4, and in this state passes to the absorption towers.

There are twelve units of absorption towers, and two towers to a unit, connected in series. The structural steel for the towers is heavily coated with pitch, to protect it against corrosion. The towers are built of acid-proof brick laid in acid-proof cement and are 35ft. square by 60ft. high. Each tower is divided by interior brick walls into four compartments. The first tower of each unit is packed half way up with six-in. spiral rings, and the upper half with three-in. spiral rings. The second tower of each unit is packed entirely with spiral rings of the three-in. size. These rings are supplied by the Chemical Construction Co.

The gas from the oxidation towers passes into the first absorption tower of each unit. The liquid pursues a course through the compartments of the two towers of each unit opposite to that taken by the gas, the liquid discharged from each compartment being used to feed to the top of the next forward compartment in the series. The liquid therefore becomes progressively stronger in nitric acid as it passes from one compartment to another, until it has strength of 50 per cent.

Ammonium Nitrate.

Ammonium nitrate is made by merely contracting the dilute nitric acid with the ammonia, care being taken so to speed the re-action that there is not too much heat evolved.

After the plant was completed, it was tested in sections by officers of the Ordnance Department to see if the product came up to the specification which called for 97 per cent. pure ammonium nitrate with not more than the following impurities: One per cent. of moisture; .02 per cent. of acidity; .01 per cent. of metallic cyanides, and .01 per cent. of thiocyanates.

It was found that the nominal cost of production would have been 5.14 cents per lb., whereas the Government had been paying 17½ cents.

Two other similar plants were started during the war at Toledo, and at Cincinnati, each for a capacity of 55,000 tons of ammonium nitrate per year, and at the time of the Armistice, they were about one-third completed. The total expenditure on these two plants would probably have been 60 million dollars in addition to the 110,000 million dollars spent at Mussels Shoals.

The Naval Department started to build a synthetic ammonia plant in Maryland, and plans were well forward for starting several arc plants to utilise off peak electric power in various centres.

It will thus be seen that, although the Americans were slow in getting into the war, they lost no time afterwards and there was a complete recognition of the fact that the safe way to meet the demand for explosives was to manufacture nitric acid and ammonium nitrate from the air.

Future of the Plant.

After the war was over, the question arose as to what was to be done with the plant at Mussels Shoals, and there were several Government enquiries, at one of which I gave expert evidence.* The politicians took sides, the Democrats and the farming interests being favourable to its being worked under some Government control to make cheap fertilisers.

* See Hearing before the Committee on Agriculture and Forestry of U.S. Senate, 66th Congress, 1920

In November, 1919, Mr. Kahn introduced a Bill into the House of Representatives at Washington, D.C., asking for further monies and powers to carry on. The preamble of Bill L3390 reads :—

A Bill to provide further for the national defence to establish a self-sustaining federal agency for the manufacture, production and development of the products of atmospheric nitrogen for military, experimental and other purposes; to provide research laboratorise and experimental plants for the development of fixed nitrogen production and for other purposes.

In connection with this Bill, the nitrate division of the Ordnance Department prepared many data to show the trend of the demand for fertilisers, etc., and I have selected Figs. 17 and 18 from some of them which are self explanatory.

The Bill did not go through, and eventually it was decided to ask for tenders from firms to take over the plant and work it.

Mr. Henry Ford's proposal seems to be the most favoured by impartial people in the States, and so it may be of interest

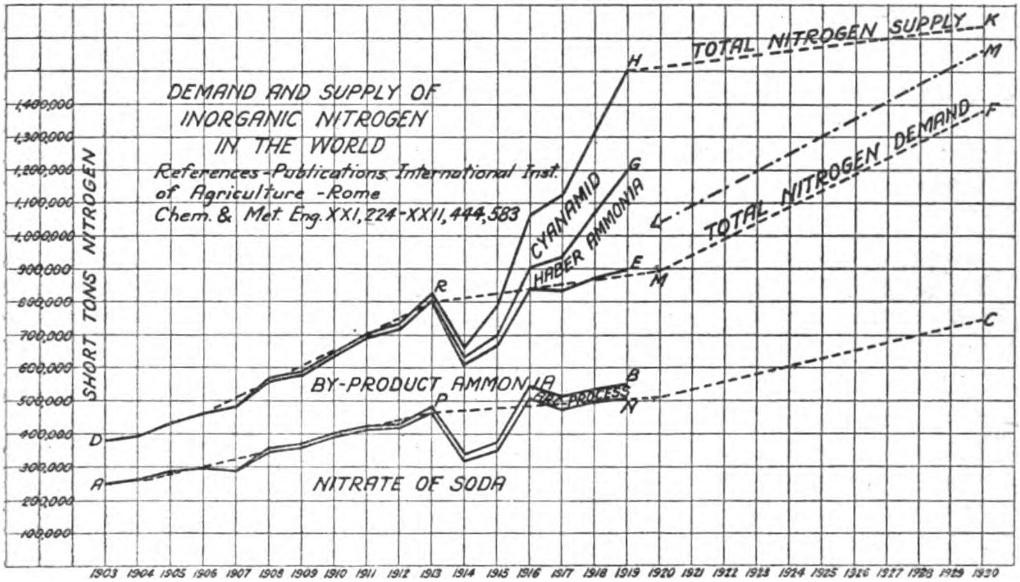

FIG. 17.

The full line curves show the supply of nitrogen up to 1919, and the dotted lines show the probable trend to 1930. Up to the beginning of the war the increases were additive or arithmetical and not geometrical. Lines MF and NC are drawn parallel to DR and AP, but it is possible that the total nitrogen demand of the world may approximate to the dot and dash line.

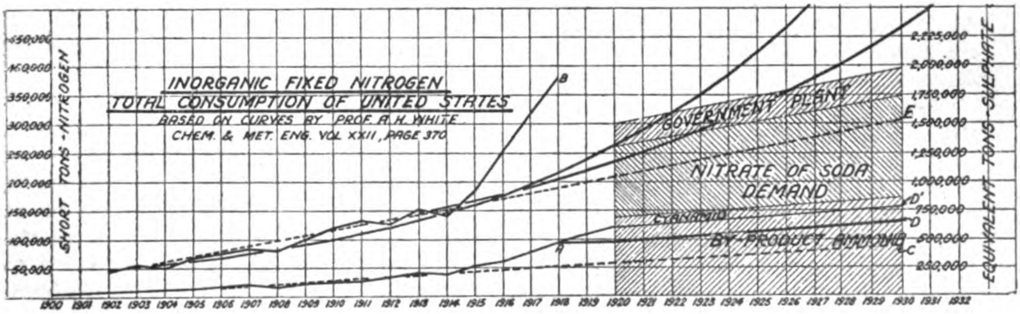

FIG. 18.

During the war Prof. A. H. White was in the Nitrate Division of Ordnance, and the curves are deduced from statistics available to the U.S. Government. It is a moot question whether the increase will follow the upward curving lines or whether it will follow a straight line law. The uppermost hatched section marked Government plant refers to Mussel Shoals, Ala.

to give the principal particulars. It is proposed to spend 25 million dollars to finish the present dam and 25 million dollars on further hydraulic works; also 25 million dollars on a second balance dam up the river. It is estimated that another four million dollars will be required for re-modelling the synthetic ammonia plant; ten million dollars for re-modelling the cyanamid plant; and 15 million dollars on a phosphoric acid plant. This makes a further total of over 100 million dollars, in addition to the 110,000 millions which it has already cost.

The phosphoric acid plant proposed in the Ford offer is interesting because the fertiliser which it is proposed to make is a combination of ammonia and phosphoric acid.

Comparative Criticism.

As a means of making nitric acid from atmospheric nitrogen, the cyanamid process is a complicated, lengthy and costly business because there are so many different steps. Yet it was accepted by Government officialdom during the war, and largely for the reason that company promoting heads of cyanamid companies found it easy to impress political, legal and other non-scientific heads of Government departments.

Before and during the war I pointed out objections to the cyanamid process when in the country, and in 1918 read a paper in U.S.A. making a detailed comparison between it and the arc process.* I pointed out that from coal and limestone to finished nitric acid the process involved seventeen distinct operations and sets of plant, the use of eight raw materials and eight different sets of skilled workmen. Whereas the arc plant required only two operations and three raw materials, very little labour, and that plants could be erected very quickly.

To-day the cyanamid process is a dead letter so far as this country is concerned, for the company has gone out of business, and, incidentally, several millions of British money have disappeared.

I personally feel strongly about it, because the company promoting methods and the ultimate failure of the cyanamid group have reacted detrimentally on fixed nitrogen development. The general public does not know differences between various processes and what technical and financial results have been and can be obtained. Therefore I welcome this opportunity of giving the facts.

Power Required.

It has been stated that the amount of power required for a given quantity of nitric acid produced by the cyanamide process is less than that required by the arc process. That was, in fact, a principal argument used during the war, the idea being that it was fair to compare only the amount of electric energy used in furnaces and for motors.

But that is an entirely erroneous way to make the comparison, for obviously, every single item of power must be taken into account. In the arc process the total energy is easily and accurately measured—that is the beauty of all electrical processes. But with the cyanamide process the energy required is not merely that in the carbide furnaces, cyanamid ovens, catalysers and motors for blowers, pumps, etc., but it includes energy to operate the liquid air process, and the boilers to supply steam for the autoclaves and other chemical operations.

In addition, it must necessarily include all the energy required for mining the coal and quarrying the limestone for the carbide; the energy for distilling the coal into coke and crushing it, for burning the limestone, and making electrodes. Locomotive power for transporting all these materials must be included; in fact, a hundred and one items which it is difficult to estimate, but which are, nevertheless, required to make the process complete.

Comparisons in any other way are utterly fallacious.

Ammonia to Nitric Acid.

Ammonia can be converted into nitric oxide by passing it, with air, through a catalyst of platinum. By using air enriched with oxygen for oxidising the ammonia, the yield can be increased, and by-product oxygen, can, of course, be taken from the liquid air process. Care must be taken to have all the gases pure, because a platinum catalyst is easily poisoned.

The possibility of converting ammonia to nitric oxide and then to nitric acid, is really a war-time proposition, but as some seem to think it is feasible peace times, I make the following remarks.

* See paper on Electric Power for Nitrogen Fixation read at the 34th Annual Convention of the American Institution of Electrical Engineers, June 27th, 1918.

Assuming that there is a market for the ammonia, then to convert any of it into nitric acid is economically unsound, for there must be a loss, and, of course, the plant for bringing about the conversion is expensive, more especially the catalyzer, which must be of platinum.

Nitrogen, whether in the ammonia form or the nitric form, is about the same price per unit, and therefore to change it from one form into another form, which can only sell at about the same price per unit, is manifestly absurd. In war times anything is done, but even then it would be best to leave ammonia as it is, and make enough nitric acid in *direct* ways to combine with it to make aneatol.

Cyanamid Fertiliser.

The product obtained from the cyanamid ovens goes by the name of lime nitrogen, and it contains about 60 per cent. of cyanamide, 18 per cent. of free lime, 12 per cent. of carbon and 1½ per cent. of unchanged carbide of calcium. This carbide has to be hydrated out before making ammonia by means of autoclaves.

When cyanamid fertiliser is required, further water has to be added to hydrate the lime as well, and dustiness reduced by adding oil. The water and the oil must be finely sprayed and the material well agitated to keep down the temperature, as otherwise there is danger of formation of dicyanodianamid, which is toxic to plants and kills nitrifying bacteria.

Cyanamid acts in most soils as follows :—(1) Calcium acid cyanamid ; (2) free cyanamid ; (3) urea ; (4) ammonia. Some dicyanadiamid is also formed. Free cyanamid and dicyanodiamid are toxic to certain nitrifying soil bacteria, and nitrification cannot take place until these injurious compounds are dissipated or changed.

Normal oxidation of the ammonia is retarded, and it is, therefore, advisable to apply cyanamid along with a nitrate form of nitrogen to all crops that are unable to grow well with ammonia alone. When conditions are just right, cyanamid is a good plant food, but when conditions are not favourable, cyanamid may be not only valueless, but injurious.

Ammo-phos and Phosphazote.

In mixed fertilisers the cyanamid is about 50 lbs. to the ton. If in larger quantity, it reacts with the acid phosphate and causes it to revert to the insoluble form. Phosphate rock, as mined, is usually in the insoluble dibasic form, and is treated with sulphuric acid to convert it to the soluble form.

It can be in larger quantities with phosphate that has been calcined, and this calcining can be done by heating phosphate rock with nitre-cake and carbonaceous material in a kiln.

To meet the objection against cyanamid being used with acid phosphates the American Cyanamid Co. introduced a compound called ammo-phos, made by combining ammonia with phosphoric acid, the latter being made from phosphate rock by the use of sulphuric acid, or by the electric furnace.

Ammo-phos is a gray and granular material that looks and feels very much like good dry acid phosphate. It may contain 13 to 20 per cent. ammonia, and 20 to 47 per cent. available phosphoric acid ; so any desired ratio of ammonia nitrogen to phosphoric acid can be obtained. Both constituents are about five-sixths soluble in water, and almost entirely soluble in the standard solutions for testing availability. The product is neutral, will keep, and can be mixed in with potash salts.

Phosphazole is the trade name given to a fertiliser made from cyanamid in Switzerland and Sweden. It has the nitrogen in the form of urea and the phosphorus in the water soluble form, and it is made by the action of carbonic acid, free cyanamide being first prepared from a solution of calcium cyanamide, and then transformed to urea.

The Swiss method uses excess sulphuric acid in the second stage of the transformation, which is afterwards used to act upon phosphate rock to change it to mono-calcium phosphate. The final product is a neutral body containing about 12 per cent. of urea and 12 per cent. of phosphoric acid.

Unlike cyanamide, phosphazote has no action on the skin, or on the bags in which it is packed. It is now being used for fertilising grape vines. The large carbide factory in Dalmatia has a licence to make phosphazote, and that factory can manufacture very cheaply. It is at present supplying most of the carbide of calcium used in Great Britain, the rest being from a Swiss company which has a large cyanamide factory on the German side of the Rhine, near the frontier.

CYANIDE AND NITRIDE.

When alkali or alkaline earth bases are heated in air with carbon, cyanides are produced, and many chemists have tried to commercialise this for fixation of nitrogen. Prof. Bucher, for example, received financial assistance from the U.S. Government during the war to try out a modification in which he used a mixture of soda ash, powdered iron and powdered coke at a high temperature, in the presence of nitrogen gas.

A plant was built at Saltville, Va., designed to give ten tons of cyanide per day, but although some cyanide containing five to ten per cent. of nitrogen was produced, the mechanical and chemical difficulties proved to be too great.

Researchers at the Fixed Nitrogen Research Laboratory at Washington, D.C., stated that the failure was due in part to low quality of the carbon and also to the iron.

In this country, the Scottish Cyanides Company tried with barium instead of sodium compounds, and it was found that the behaviour of the reagents was different, for a carbide forms which takes up nitrogen to yield a mixture of cyanide and cyanamid, the last named ultimately combining with a further quantity of carbon to form cyanide.

The reactions with barium result in formation of carbide and cyanamide, and finally barium cyanide, as follows :—

$$BaO + C = Ba + CO$$
$$Ba + 2C = BaC_2$$
$$BaC_2 + N_2 = BaCN_2 + C$$
$$BaCN_2 + C = Ba(CN)_2$$

and the decomposition of the barium cyanide with steam at about 400°C gives ammonia as follows :—

$$Ba\,(CN)_2 + 4H_2O = 2NH_3 + Ba\,(OH)_2 + CO$$

More recently Mr. Kenneth M. Chance has been working at the problem, and at the annual general meeting of the British Cyanides Co., Ltd., last July, he made these references :—

The fixation of atmospheric nitrogen, as it concerns this company, has two stages. The first stage is where we can obtain from the nitrogen of the atmosphere raw material in unlimited quantities for the cyanogen products which we manufacture. The second stage will be when we can fix atmospheric nitrogen at a sufficiently low cost to convert it into ammonia at a price which will enable us to compete with any other method of manufacturing ammonia. . . . . .
On the recommendation of the General Staff Committee, the Board have to-day given instructions for estimates to be prepared for a plant for manufacturing cyanogen from the nitrogen of the atmosphere.

There is an ever increasing demand for cyanides. Hitherto the uses have been principally for the hydro-metallurgy of gold and silver ores, with smaller quantities for case-hardening and electro-plating, but hydro cyanic acid is coming into use as a fumigating agent for fruit trees, and there are also other uses for cheap cyanides.

Aluminium Nitride.

Some metals have an affinity for nitrogen, and form nitrides, which contain up to 50 per cent. of nitrogen, and the nitrogen can be liberated again as ammonia.

Various processes depending on this have been proposed, and the one which has attracted most attention is that of Serpek. He proposed to make aluminium nitride, because of the prospect of associating fixation of nitrogen with the production of pure alumina for the manufacture of aluminium.

The method utilises a mixture of impure alumina as bauxite, and carbon or coal, and the alumina was partly converted into carbide, which reacted with the remaining alumina to produce free aluminium, the latter then combining with nitrogen and forming nitride.

In consequence of the heat of formation of aluminium oxide, the reaction of alumina and coal is strongly endothermic. The temperature necessary to effect the reaction ranges up to 1800°C., but the absorption begins slowly at about 1100°C.

The nitrogen in producer gas can be used, but the reaction is a reversible one, and the equilibrium conditions depend on the concentration of carbon monoxide gas. Therefore, the use of producer gas which contains a large percentage of carbon monoxide, necessitates the use of higher temperatures for the reaction than would be the case with pure nitrogen.

The complete reaction can be represented by the following equation :—

$$Al_2O_3 + 3C + N_2 = Al_2N_2 + 3CO.$$

Electricity is used for raising the temperature, and if one reckons only that kind of power, then it amounts to 12 k.w. hours per k.g. of nitrogen fixed, equivalent to 1.42 k.w. years of 8,500 hours per metric ton of nitrogen fixed.

It should be noted that even if the Serpek process was a real success, the amount of

fixed nitrogen that could be made in connection with the aluminium industry would be relatively small. For example, assuming the world's output of aluminium at 70,000 metric tons, then if the whole of the alumina required was made by the Serpek process, the amount of sulphate of ammonia recovered would be 170,000 metric tons.

In the United Kingdom the output by Serpek process could only be about five per cent. of the present output of ammonium sulphate from coke ovens and gas works. Therefore, although the process is interesting, and must necessarily be mentioned in these lectures, it does not "cut much ice," as the Americans say.

CORRESPONDENCE.

YUCATAN LABOUR COSTS IN SISAL PRODUCTION.

In the Journal of 28th September, page 771, on costs of producing sisal (Hennequin), is the item of $125,000.00 being capital invested in plantation, machinery, etc., which probably needs the following elucidation :—

COST OF ESTABLISHING AND EQUIPPING A SISAL PRODUCING PLANTATION.

It takes five years for a plantation to reach full production. When in full production the plants will yield 35 leaves per plant per annum.

Throughout Tropical America there are only about 250 working days per year.

A factory of economical capacity should handle 125,000 leaves per day ; requiring 892,857 plants, yielding 31,250,000 leaves annually. 1,000 leaves yield 60lbs. of fibre.

PLANTATION COSTS.

	$
1,000 acres @ $10.00 per acre ..	10,000.00
Cost of cleaning per acre, $6.00 ..	6,000.00
Cost of 892,857 plants, $30.00 per 1,000	26,785.71
Cost of planting 892,857 plants, $10.00 per 1,000	8,928.57
	$51,714.28
Interest on $51,714.28 for 5 years @ 6%	15,514.28
Total cost of plantation	$67,228.56

EQUIPMENT OF PLANTATION.

	$
Decorticators	6,000.00
Boiler and engine	5,487.50
Elevators and transmission	1,250.00
Hydraulic press	1,000.00
Transmission equipment	1,000.00
Freight from port	1,000.00
Installation	7,500.00
Drying stands	500.00
Building foundations	1,750.00
Factory buildings	5,000.00
Managers' and employees' quarters, warehouses, stable and fixtures ..	5,000.00
30 mules	3,000.00
25 wagons	1,875.00
	$40,362.50
Interest on $40,362.50 one year at 6%	2,421.75
	$42,784.25
Cost of plantation	67,228.56
Cost of equipment	42,784.25
Overhead for five years	15,000.00
	$125,012.81

During the fifth year the plants will commence to yield new shoots.

All of these figures vary with difference of location ; land values, plant yield and labour costs are controlling factors and subject to local conditions.

G. A. LOWRY.

REPORT ON THE SOCIETY'S EXAMINATIONS, 1923.

In the above-mentioned report, published in the *Journal* of October 26th, the Examiner in Type-writing states (page 850) that the word "celluloid" was spelt in twenty different ways.

The cause of misspelling is always *mis-pronunciation.*

Until the Government provides a "Primer of the King's English" (*i.e.*, what the King himself says) the people will continue to obey the first law of Nature, which is, that the hand shall follow the movements of the vocal organs.

If the pupil *spells* "cyellerloid" it is because he *says* "ç-yell-err-loid" (çyell-err-loid). The *normal* sound and pronunciation of the letter "u" is heard in "lull," which he pronounces "lurl" hence the spelling "er" for "ul." The two pronunciations of the letter "u" in "full" and "futile" are exceptional. The printer is perfectly able and willing to indicate these exceptional phonetic values of the letter; why not allow him to do it, or rather, insist that he shall do it, in an educational print? If the word "celluloid" was spelt in twenty different ways, then the Government is to blame for allowing twenty different dialects to be taught in their schools.

It is unjust and tyrannical to force the "New Poor," who themselves speak the King's English, to send their children to schools, where they hear and acquire only the vulgar and common dialect of boys who scream and howl in the neighbourhood.

The mistakes quoted by the French Examiner, on page 853, "nous laissent," "nous marcher," "nous achetent," are again due to mis-pronunciation or want of oral teaching.

Language is first spoken and then written. It is impossible for children in the lower standards to say "nous marcher," etc. The ear forbids it. Seven thousand words can be easily said in an hour, and thus hundreds of repetitions of the sound "nous" followed by the sound "ons" will effectually prevent any such faulty spelling. We need International Schools, such as are found in Naples, where no child is forced by Printers, Teachers and Inspectors to disobey the Laws of Nature."

ANNA DEANE BUTCHER.

WOOL, CAMEL'S HAIR AND CASHMERE INDUSTRIES OF CHINA.

Tientsin is the principal market for the wool trade of North China. Although practically every Province north and east of the Yangtsze River produces wool, 50 per cent. of all the wool exported from Tientsin comes from Kansu and the Tsinghai district of Mongolia, 15 per cent. from Shansi and Shensie, and 25 per cent. from the rest of Mongolia. In 1922, according to statistics compiled by the Chinese Maritime Customs, exports of wool from Tientsin amounted to 58,148,400 pounds, as compared with 53,819,067 pounds in 1921 and 10,906,790 pounds in 1920. In all, 90 per cent. of the export of China wools was from the port of Tientsin.

According to a report furnished by the United States Consul-General at Tientsin, there are no authentic figures showing the number of sheep in China. One estimate places the figure at 25,000,000 but this is merely an approximation. Generally speaking, the sheep are of a very poor variety and, except in the grasslands of outer Mongolia, they are found in extremely small herds, receiving but little care and existing on the scantiest of herbage. The most primitive methods are also in use among the large herds in outer Mongolia. The excessive snowfall of the winters and the severe droughts which occur during the summer months tend appreciably to reduce the yield.

There is a very wide variation in staple, quality, colour, and scoured yield of China wools. While many are fair working wools, the majority lack elasticity or springiness, with the result that the yarn is lean or flat. They are used almost exclusively in the manufacture of carpets, although during the period from 1917 to 1919, owing to the shortage of supplies from other parts of the world, some of the finest grades were used in the manufacture of clothing.

China wools are divided into three distinct grades, known to the trade as strictly combing, semi-combing, and filling wools. Tsinghai or Hsining and Szechwan wools make up the bulk of the strictly combing and semi-combing wools, and Mongolians, Hatta, Woosie, Ball, Kinchow, Liangchow, Hsihtsui, Shansi, Kalgan, and Manchurian make up the greater portion of the filling wools. Hsining wool is known to the American trade as a wool of medium length staple, carrying a fine undergrowth as compared with other filling wools and exhibiting considerable kemp.

The sheeps' wool is collected from the farmers and transported to one of the numerous central markets which are scattered throughout the wool-producing Provinces. Waterways, oxcarts, and camel caravans are the chief means of transportation, and the cargo is usually several months in transit before it reaches its final destination at the port of export.

In the Tientsin district wool is purchased from the individual producers by agents of Chinese wool dealers and representatives of the compradores associated with foreign wool firms of Tientsin. Hsining is one of the most important of the interior wool marts and Kalgan is another. At these more remote markets the services of brokers and middlemen are necessary. Certain inn-keepers combine that business with the purchase of wool as brokers or intermediaries and conduct private wool exchanges in their respective inns.

Upon the arrival of the wool in Tientsin brokers representing the dealers and the compradores sample the various parcels to the different foreign firms and the stock is eventually sold to the firm which makes the most advantageous offer. A compradore is associated in business with a foreign firm, from which he obtains the advance of funds under certain guarantees and also the transit passes, under which the cargo is brought out with exemption from interior taxation on its movement on the ground that it is intended for export. In consideration of this he is under obligation to offer wool brought in by him to his own firm first. Should that firm refuse him, on account of either price or quality, he is at liberty to offer the cargo to other firms. When a sale is conducted the seller pays a commission to the compradore through whose agency the transaction was consummated. As stated above, wool is also brought in by dealers and sold to the foreign firms through brokers in Tientsin. The wool season at Tientsin is from October to February. Receipts are heaviest in November, December and January.

After the wool has been purchased by the foreign exporter, it is selected and graded, after which the combing and semi-combing wools are shaken by hand and the filling wools are machine cleaned for the purpose of removing the foreign matter, which frequently amounts to 40 or 50 per cent. by weight. This is done to reduce the cost of transportation overseas. The cargo is shipped in press-packed bales averaging 500 pounds per bale.

Camel's hair is obtained from the Mongolian and Turkestan camel. The product obtained from the camels from north-eastern Mongolia is much darker and much coarser than that from other localities because the camels there are worked harder than they are in the western districts. The poorest

quality of all is obtained from the animals engaged in transporting coal. This grade is practically valueless.

The trade is of very old standing, the best hair formerly going to Russia, where it was used for padding clothes, but during the last century trade sprang up with the United States and England.

Camel's hair is shed and not clipped, as is popularly supposed. The best quality goes into the manufacture of high-grade underwear, the second quality into a cheaper grade, and the rest is used in the manufacture of press cloths. There is also a limited amount of this wool used locally in the manufacture of rugs. Statistics for this industry, compiled by the Chinese Maritime Customs, show that the exports of camel hair from the port of Tientsin in 1922 were 8,460,127 pounds, as compared with 3,791,867 pounds in 1921 and 4,715,300 pounds in 1920.

Cashmere exports from Tientsin were 2,693,867 pounds in 1921 and 1,178,667 pounds in 1920. Nearly all of this commodity, obtained from the cashmere goat, is exported from Tientsin, although there is a small supply from some of the lower Yangtsze ports and from Ningpo.

GENERAL NOTES.

India and the Empire Exhibition.—At an All-India Conference of Exhibition officers held at Bombay recently it was decided to organise an additional section in the Indian Pavilion, to be called the Central Co-operative and Educational Section. Bengal is holding a preliminary exhibition at Calcutta, before the exhibits of that presidency are forwarded to London. It is announced that special facilities on board ship and in London have been provided for orthodox Hindus coming to England for the Exhibition. The Government of the Maharaja of Mysore will arrange for the transport and exhibition free of cost of all exhibits sent from that important State through the local Department of Industries.

Use of Gas in Brewing.—A development of the use of gas in industry—the firing of coppers in which beer is boiled at breweries—was described in a paper read at the Twelfth Annual Conference of the British Commercial Gas Association by Mr. William Wilson, Engineer and Manager of the Gas Department at Burton-upon-Trent, where experiments with the new method were first made in the model brewery of Messrs. Samuel Allsopp & Sons, Ltd., about three years ago. The normal capacity of the copper with which the tests were made was not less than 80 barrels, or 2,880 gallons. The wort, the extract of malt, began running in at a temperature as near 145° F. as possible, and as soon as the copper bottom was covered two of the gas burners were lighted, the remainder being brought into action gradually as the copper filled. In about three hours' time, when the copper was full, the whole of the contents was boiling vigorously—and was kept boiling for about four hours. It is claimed that the advantages of obtaining the necessary heat by gas instead of coal are chiefly convenience and cleanliness. Apart from this, with gas the rate of boiling was found to be under better control and much more steady, while the wear and tear on the copper bottom, which in the usual course had to be renewed periodically at great expense, was reduced to a minimum. Recently Messrs. Bass & Co. have made similar tests with no less satisfactory results, and there is said to be every promise of the objection on the score of cost being overcome in the immediate future by the recent invention of gas burners for the purpose, which have a very high efficiency.

MEETINGS OF THE SOCIETY.

Ordinary Meetings.

Wednesday evenings, at 8 o'clock :—

November 14.—Monsieur Edouard Belin, "Téléphotographie, Télautographie, Télévision," avec Experiences et Projections. Alan A. Campbell Swinton, F.R.S., will preside.

November 21.—J. A. Knowles, "Forgeries of Ancient Stained Glass." The Earl of Crawford and Balcarres K.T., P.C., will preside.

November 28.—Sir Henry John Gauvain, M.A., M.D., M.Ch., Medical Superintendent of the Lord Mayor Treloar Cripples Hospital, "The Effect of Sun, Sea and Open-air in the Treatment of Disease." The Right Hon. Arthur Neville Chamberlain, M.P., will preside.

December 5.—Arthur William Hill, M.A., Sc.D., F.R.S., F.L.S., Director of the Royal Botanic Gardens, Kew, "The Work of the Royal Botanic Gardens, Kew." Charles Albert Seward, M.A., F.R.S., F.G.S., F.L.S., Professor of Botany in the University of Cambridge, will preside.

December 12.—Sir Frank Baines, C.B.E., M.V.O., Director of Works, H.M. Office of Works, "The Preservation of Historic Buildings and Ancient Monuments." Sir Aston Webb, K.C.V.O., C.B., P.R.A., will preside.

Indian Section.

Friday afternoons, at 4.30 o'clock.

December 7.—William Foster, C.I.E., B.A., Registrar and Superintendent of Records, India Office, "The Archives of the Honourable East India Company." (Sir George Birdwood Memorial Lecture.)

DOMINIONS AND COLONIES SECTION.

Tuesday afternoon, at 4.30 o'clock.

NOVEMBER 27.—THE VISCOUNT BURNHAM, C.H., LL.D., D.Litt., M.A., "The West Indies." LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, will preside.

DECEMBER 17 (Monday.)—WM. C. NOXON, Agent-General for Ontario, "Emigration within the Empire."

PAPERS TO BE READ AFTER CHRISTMAS.

G. ALBERT SMITH, "Cinematography in Natural Colours—further developments" (with illustrations—scenes from H.R.H. The Prince of Wales's Tour in India).

IYEMASA TOKUGAWA, O.B.E., First Secretary to the Japanese Embassy, "The Earthquake and the Work of Reconstruction in Japan."

SIR RICHARD ARTHUR SURTEES PAGET, Bt., "Fused Silica and its use as a Refractory Material."

H. MAXWELL LEFROY, M.A., Professor of Entomology, Imperial College of Science and Technology, "The Preservation of Timber from the Death Watch Beetle."

T. THORNE BAKER, "Photography in Industry, Science and Medicine."

SIR RICHARD M. DANE, K.C.I.E., Commissioner North India, Salt Revenue, 1898-1907; Foreign Chief Inspector, Salt Revenue, China, 1913-18, "Salt Manufacture in India and China."

BRIGADIER-GENERAL HENRY ALFRED YOUNG, C.I.E., C.B.E., late R.A., Director of Ordnance Factories, India, 1917-21, "The Indian Ordnance Factories."

JOCELYN F. THORPE, C.B.E., D.Sc., Ph.D., F.R.S., F.I.C., F.C.S., Professor of Organic Chemistry, Imperial College of Science and Technology, "Chemical Research in India."

COLONEL H. L. CROSTHWAIT, C.I.E., R.E., retd., late Superintendent, Survey of India, "The Survey of India."

BHUPENDRA NATH BASU, M.A., Vice-Chancellor of Calcutta University, "The Vedantic Philosophy of the Hindus."

F. W. WALKER, "The Commercial Future of the Backward Races, with Special Reference to Papua."

F. F. MARRIOTT, "The Oil Industry of Sarawak."

Friday afternoons, at 4.30 o'clock.

January 4, 18, February 15, March 21, May 2.

DOMINIONS AND COLONIES SECTION.

Tuesday afternoons, at 4.30 o'clock.

February 5, March 4, April 1, May 27.

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

SAMUEL HENRY DAVIES, M.Sc., F.I.C., "The Cultivation of Cocoa in British Tropical Colonies." Two Lectures. November 12, 19.

LECTURE I.—Choice of soil and climate. Selection of seed—recognised varieties. Planting out seedlings. Use of windbelts—temporary and permanent shade trees—trenching—manuring—weeding.

LECTURE II.—Extirpating disease. Collecting and breaking pods. Fermenting, drying and shipping the bean. Characteristics of the more important varieties. Statistics of world production and consumption.

ALDRED F. BARKER, M.Sc., Professor of Textile Industries, The University, Leeds, "Recent Progress in the Wool Industries." Two Lectures. December 3, 10.

ERIC KEIGHTLEY RIDEAL, M.B.E., B.A., Ph.D., D.Sc., F.I.C., The Chemical Laboratory, The University Cambridge, "Colloid Chemistry." Three Lectures. January 21, 28; February 4.

EDWARD VICTOR EVANS, O.B.E., F.I.C., Chief Chemist, South Metropolitan Gas Company, "A Study of the Destructive Distillation of Coal." Three Lectures. February 25; March 3, 10.

COBB LECTURES.

Monday evenings, at 8 o'clock.

DR. T. SLATER PRICE, Director of Research, British Photographic Research Association, "Certain Fundamental Problems in Photography." Three Lectures March 24, 31; April 7.

DR. MANN JUVENILE LECTURES.

(*Special tickets are required for these Lectures*).

Wednesday afternoons, at 3 o'clock.

DR. WILLIAM ARTHUR BONE, F.R.S., Professor of Chemical Technology, Imperial College of Science and Technology. "Fire and Explosions." Two Lectures. January 2, 9. The Lectures will be fully illustrated with experiments.

MRS. JULIA W. HENSHAW, F.R.G.S., Croix de Guerre, "Among the Selkirk Mountains of Canada (with ice-axe and camera)," One Lecture. January 16. The Lecture will be fully illustrated with hand-painted lantern slides.

Journal of the Royal Society of Arts.

No. 3,704. VOL. LXXI.

FRIDAY, NOVEMBER 16, 1923.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2)

NOTICES.

NEXT WEEK.

MONDAY, NOVEMBER 19th, at 8 p.m. (Cantor Lecture.) SAMUEL HENRY DAVIES, M.Sc., F.I.C., "The Cultivation of Cocoa in British Tropical Colonies." (Lecture II.)

WEDNESDAY, NOVEMBER 21st, at 8 p.m. (Ordinary Meeting.) J. A. KNOWLES, "Forgeries of Ancient Stained Glass." THE EARL OF CRAWFORD AND BALCARRES, K.T., P.C., will preside.

Further particulars of the Society's meetings will be found at the end of this number.

FIRST ORDINARY MEETING.

WEDNESDAY, NOVEMBER 7th, 1923; LORD ASKWITH, K.C.B., K.C., D.C.L., Chairman of the Council, in the Chair.

The following candidates were proposed for election as Fellows of the Society:—

Ashbolt, Hon. Alfred Henry (Agent General for Tasmania), London.
Bartlett, Miss Eveline, L.R.A.M., London.
Batchen, Thomas Mackenzie, M.Inst.C.E., Dublin.
Berger, Joseph Archibald, London.
Bhaduri, J. N., Bengal, India.
Brown, Professor Robert Scott C., Dunedin, New Zealand.
Burns, Patrick, Alberta, Canada.
Cama, T. R. N., Poona, India.
Cohen, Rex David, Shrewsbury.
Corbett, Harold Lester, Ottawa, Canada.
Craster, Walter Spencer, M.I.M.E., Rhodesia, South Africa.
Dalal, M. B., Karachi, India.
Dan, Satya Kumar, Calcutta, India.
De, Rajendra Nath, Calcutta, India.
De, S. N., M.Sc., Calcutta, India.
Dimock, Weston P. B., A.M., Ph.D., M.A.C.S., Maine, U.S.A.
Foster, Romulus Adams, M.D., Washington, D.C., U.S.A.
Graham, Rev. Joseph William, M.A., Jamaica, British West Indies.
Hamid, Abdul, Tanganyika Territory, Africa.
Hancock, Clarence Coles, London.
Harris, Norman, Rugby.
Jowitt, James Edward, Calcutta, India.
Keil, Henry William, Camberley, Surrey.
Kett, Rev. George, Cape Province, South Africa.
Laite, William James, Cape Town, South Africa.
Lab, Roshan, F.C.I., Rajputana, India.
Lang, William Lockwood, Saltash, Cornwall.
Leonard, Charles Hare, London.
Lin, Mg We, B.A., K.S.M., Bassein, Burma.
Lively, Chauncy Clinton, Ph.D., Sc.B., A.M., Charleroi, Pennsylvania, U.S.A.
Logan, Prof. Willlam Newton, A.M., Ph.D., Bloomington, Indiana, U.S.A.
Lyan, Choo Kyin, B.A., Prome, Burma.
McDougall, Principal Alexander Hiram, B.A., LL.D., Ottawa, Canada.
McNish, John, London.
Maskill, Joseph Francis, B.A., F.S.S., London.
Mayo, Robert W. B., M.D., Baltimore, Maryland, U.S.A.
Miles, Albert G. J., West Croydon, Surrey.
Miles, Edmund Lancelot, M.E.I.C., Ontario, Canada.
Mills, William Stephen, Wallasey, Cheshire.
Munday, R. L., Bath, Somerset.
O'Brien, William John, O.B.E., M.L.A., Pietermaritzburg, South Africa.
Pearse, William Worth, B.Sc., Toronto, Canada.
Percey, Leonard Rivers Norman, London.
Pettee, Charles Leslie Wight, S.B., Hartford, Connecticut, U.S.A.
Pike, John Milton, K.C., Ontario, Canada.
Puri, Mehr Chand, Delhi, India.
Rahman, Maulvi Mohammad Musudur, Abbottabad, India.
Ranganatha, Rao Sahib Colattur, Bangalore, India.
Reid, His Honour Judge William Octavius, Jamaica, B.W.I.
Renwick, Sir Harry, K.B.E., Kingston Hill, Surrey.
Rigsby, A., Swadlincote, Burton-on-Trent.
Robinson, William J., M.D., New York City, U.S.A.
Samuel, John, Treorchy, Glamorgan.
Sarup, G. Bishan, F.C.I., Oudh, India.
Schueler, Julian L., Peoria, Illinois, U.S.A.
Simmons, Archibald Guy, M.C., London.
Sinha, J. N., Balawali, U.P., India.
Springer, Milton Earl, Manila, Philipine Islands.
Tarrant, Henry William Richard, Olton, Warwickshire.

Thorn, Major John C., M.C., Vancouver, British Columbia, Canada.
Trenor, Albert Delafield, Gloucester, Massachusetts, U.S.A.
Twomey, Patrick Victor O'Connor, Limerick, Ireland.
Varadachari, Perungavar, London.
Varma, Parsotamdas Govind Prasad, Lucknow, India.
Waddie, H. J., Ontario, Canada.
Watson, Arnott E., Lahore, India.
Watson, Charles Albert, Keighley, York.
Whitney, Willis Rodney, Ph.D., Schenectaday, New York, U.S.A.
Whitworth, John, A.R.C.A., Alexandria, Egypt.
Wilkie, Edward Thomas Irvine, Singapore, State Settlements.

The Chairman's address on "Exhibitions" will be published in the next number of the *Journal*.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

NITRATES AND AMMONIA FROM ATMOSPHERIC NITROGEN.

By E. Kilburn Scott, A.M.Inst.C.E., M.I.E.E.

Lecture III.—*Delivered April 23rd*, 1923.

SYNTHESIS OF AMMONIA.

The synthesis of ammonia is the direct combustion of nitrogen and hydrogen, according to the equation $N_2 + 3H_2 = 2NH_3$. It is often called the Haber process, because its technical development was mainly due to Prof. Fritz Haber, but Regnault studied the problem in 1840; the French chemist, Le Chatelier, first pointed out the importance of working the synthesis at considerable pressure, and Prof. Nernst was the first to carry out experiments up to 75 atmospheres. Nernst used an iron catalyst, which was not as successful as he expected, but his work and that of Dr. Jost indicated technical possibilities.

In the meantime Prof. F. Haber had noted that good catalysing properties were possessed by such metals as uranium and osmium. With the assistance of Mr. R. Le Rossignol* researches were made up to 200 atmospheres pressure, and they found that the ammonia equilibrium at that pressure and 600°C was 6 per cent. Patents were taken out in their joint names.

A technical plant was constructed in 1909 which gave ¼ kilogramme of ammonia per hour and this was shown to Dr. Bosch, then manager of the Ludwigshaven Works, and to Dr. Mittasch, head of the research department of Badische Anilin und Soda Fabrik. As a result Dr. Mittasch wrote a favourable report and this and the enthusiasm of one of the directors, Von Brundt, caused the company to purchase the patent rights.

Large scale working brought forward difficult chemical and engineering problems, such as the manufacture of cheap hydrogen and the construction of large steel vessels to withstand the pressure. Drs. Bosch and Mittasch and engineers of the Badische and Krupp companies solved these. The first commercial plant of 25 tons a day started in 1913 is generally known by the name Haber-Bosch.

Technical Problems.

The commercial synthesis of ammonia is the most difficult chemical engineering problem that has yet been tackled, and its solution has opened up possibilities of endeavour in other directions, especially in the uses of catalysts and super pressures. The following were the most difficult points which had to be solved :—

(*a*) Cheap production of large amounts of pure hydrogen and pure nitrogen, especially the first named.

(*b*) The manufacture of steel vessels to withstand safely 200 atmospheres at a temperature approaching red heat in the case of the catalyst vessel.

(*c*) The use of a steel alloy very low in carbon so as to withstand the effects of occluded hydrogen and ammonia gases.

(*d*) The design of joints that would withstand the pressure and also vertical and lateral stresses set up by differential temperatures.

(*e*) A promoter to add to the pure iron or other main catalyser so as to increase the efficiency of the synthesis.

(*f*) Removal of the ammonia as formed in such a way as to conserve the pressure.

It was found that the structure of ordinary cast steel allowed the gases to pass through too easily and the carbons combined with the hydrogen to form methane, which

* Mr. R. Le Rossignol is a native of Jersey and therefore British. His work in making the synthetic ammonia process a success has not been generally recognised. He was a partner to the agreement when the rights were handed over to the Badische Anilin und Soda Fabrik in July, 1909.

tended to cause blisters and other dangerous imperfections. It was also found that ammonia, at the temperatures of formation or decomposition had a powerful action on iron tending completely to break down its crystalline structure, probably by nitrification.

The difficulty was overcome by using very low carbon steel made in the electric furnace and alloying it with such metals as tungsten, nickel and chromium. The Badische Anilin und Soda Fabrik uses tungsten steel and M. G. Claude uses nickel chrome steel.

German Factories.

The first factory was built at Oppau on the Rhine near Ludwigshaven and the second built during the war is at Leuna near Merseburg, Saxony. The Kaiser and his military party took great interest in the Oppau plant, especially when rumours of war began to increase.

It was foreseen that only by making explosives and fertilisers from atmospheric nitrogen could the Central Powers become independent of overseas supplies from Chili.

Before the war Germany was the largest market for Chili nitrate. To-day the country can not only make all that is required for home use, but could also export a considerable quantity if the exchange was anywhere near normal.

Towards the end of the war the Oppau factory employed 6,000 men and produced 220 tons of fixed nitrogen per day. The complete plant cost over £10,000,000, and a considerable proportion went in perfecting the process.

The Leuna factory was started in May, 1916, finished in eleven months, and by 1918 was producing 400 metric tons of ammonia per day. Since the war this plant has been doubled. Not much is known about its details, but being larger and built at a later date it is more efficient than the factory at Oppau.

The Leuna factory is associated with the ammonia soda process, and ammonia sulphate is made.

Description of Oppau Plant.

The following description is taken from accounts written by those who were authorised by the Treaty of Versailles to inspect the plant, the best published report being that of Lieut. McConnell, of the Nitrate Division of Ordnance of the U.S. Government.*

There are 15 catalyser units, each capable of producing 20 tons of ammonia per day, but as they do not all run at the same time, the maximum output is about 250 tons a day.

Each unit takes about 12½ million cub. ft. of nitrogen and hydrogen per day and about 6 per cent. is formed into ammonia, which, with the uncombined gases is then passed through absorbers and the ammonia is extracted by means of water.

About 10 per cent. of the gas is lost, as the argon and methane are allowed to accumulate to several per cent. and then the amount is reduced by blowing off.

Each catalyst bomb with its heat interchanger and absorber is placed in a bomb-proof compartment built of brick which has iron doors lined with strong planking.

Hydrogen by Catalytic Action.

When the Badische Anilin und Soda Fabrik began to develop the Haber process on a commercial scale it was seen that a principal factor was an ample and cheap supply of hydrogen. About 70 per cent. of the total cost of making synthetic ammonia goes in the preparation and purification of the hydrogen gas. After various experiments Drs. Bosch and Mittasch developed the following method.

The producers are like those for making commercial water gas and give a mixture of about 50 per cent. of hydrogen and 40 per cent. of carbon monoxide. There are 12 of the Pintsch type each measuring 15ft. by 25ft. Ruhr coke is used at the rate of 30 tons per day in each, and about three million cub. ft. are produced.

Further, hydrogen is also made with the help of the carbon monoxide by causing it to react with steam in the presence of a catalyst according to the equations—

$$CO + H_2O = CO_2 + H_2.$$

There are 26 catalyser units, each having two heat exchangers and one catalyst chamber 16ft. by 12 ft. by 10ft., and each chamber has two beds of catalyser material, consisting of oxide of iron and a promoter.

The process requires much heat and the use of a very large excess of steam, so it is distinctly expensive. The next step is for removal of the carbon dioxide; the

* See article in *Industrial and Engineering Chemistry* for September, 1918.

gases are first cooled, then compressed to a pressure of 25 atmospheres, and finally put through water scrubbers which remove most of the carbon dioxide and also about 10 per cent. of the hydrogen.

The water enters the top of eight steel towers packed with rings, each 4ft. diameter and 30ft. high, and gas enters at the bottom at slightly lower pressure. The water washes out the carbon dioxide and as it issues it drives Pelton wheels which regenerate about 60 per cent. of the power.

The small amount of monoxide which remains in the hydrogen gas is removed by eight steel towers, 2½ft. diameter and 30ft. high packed with hollow balls. The gas enters at 200 atmospheres pressure and the carbon monoxide is absorbed by ammoniacal copper formate solution. Afterwards the monoxide is drawn from the copper solution by pumping it through two steel towers. The copper solution is then used over and over again.

There are also eight additional steel towers similar to the above, through which sodium hydroxide solution is pumped for further purification of the hydrogen. The nitrogen is made by a Linde liquid air plant, similar to that illustrated in the second lecture. Gas is added to the purified hydrogen to the extent of 25 per cent.

Electric Power.

A very considerable amount of electric power is required for operating the various parts of the plant, such as compressors for raising pressure of gases to 200 atmospheres and for circulating the gases; pumps for circulating water at 200 atmospheres for absorption of ammonia, also for circulating copper formate solution and many other purposes.

This power is generated from lignite, each Kg. of which gives three cub. metres of gas containing 29 per cent. of CO and 12 per cent. of H. The gas is made in producers of the type B.A.M.A.G., which means Berlin Anhaltischer Machinenbau Aktien-Gesellschaft. Each producer measures 12ft. by 25ft., and it burns lignite briquettes 2in. by 4in. at the rate of 20 tons per day, which gives two million cub. ft. of gas per day, representing about 18,000 kilowatts.

When suggestions are made for carrying on industries in this country which require large amounts of electric power, one is often met by the remark that we cannot do as Germany and America because we have no water power, the implication being that nearly all modern industries abroad are carried on with water power. As a matter of fact, that is not so. The industries of Germany that we are now discussing are carried on with electric power generated from poor fuel, mostly lignite coal.

The largest electric power station in Europe at the present time, 185,000 k.w., was built at Bitterfeld in Germany during the war, mainly to supply energy for fixation of atmospheric nitrogen. It uses a poor quality lignite that our industrialists would sniff at. The manufacture of hydrogen gas alone at the synthetic ammonia plant at Merseburg takes 40,000 horse power, and the arc process plant built there during the war took 60,000 kilowatts all generated from lignite.

Haber Bosch Catalyst Bomb.

The bomb or vessel used at the Oppau factory is shown in Fig. 19. It consists of two forgings made by the Krupp firm of tungsten steel, containing very low carbon. Each is 19ft. 7in. long, 3ft. 9in. outside diameter and the wall is about 7 inches thick.

The end covers, 2ft. thick, are fastened down by 15 tap bolts, each 4in. diameter and the flanges of the two halves of the vessel are also held in the same way. The total weight is 74½ tons.

The vessel is lined with electrolytic iron, and the hydrogen gas passes through the lining, and is allowed to escape by numerous small holes, which are drilled through the steel.

Inside the iron lining there is a layer of refractory material, which is held by another liner, the rest of the space, about 20 inches diameter, being occupied by catalyst material. This consists of pure iron and a promoter.

The outside of the bomb is heavily lagged so as to conserve heat and keep the catalyst material at about 600° C. Electric heat is used for starting and about three days are required to get everything warmed up ready for work.

Heat Interchangers and Absorbers.

Each catalyst bomb has its own heat interchanger, which is of similar construction and of tungsten steel forgings, 19ft. 7in. diameter and 15in. inside diameter.

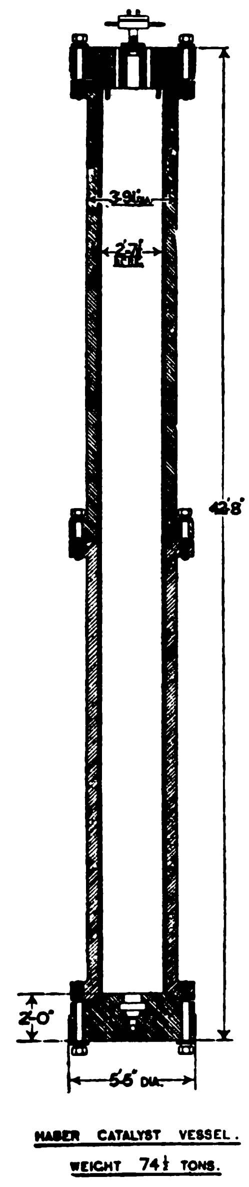

FIG. 19.—Cross section of Haber-Bosch Catalyst Bomb.

It is made of tungsten steel with a liner of pure iron and weighs 74½ tons. The contained catalyser material will deal with 20 tons of ammonia per day of 24 hours.

The inside is filled with ⅝ in. diameter steel tubes welded into steel plates at the ends.

Each catalyst bomb has also its own absorber for removing the ammonia with water under a pressure of 200 atmospheres. Each absorber has three sets of spiral steel coils one above the other, the upper being at a height of 60ft. They are water cooled.

The gases pass down the lowest spiral and then through the others in succession, whilst the absorbing water flows from top to bottom by gravity and scrubs out the ammonia as a 20 per cent. solution.

The uncombined gases then pass forward to the catalyst bomb again and have thus to be kept in continuous circulation at 200 atmospheres pressure. It is costly and complicated when compared with the Claude process, which will be described later.

Post-War Developments.

After the war, various concerns interested in the manufacture and sale of compounds made from atmospheric nitrogen formed an association called the Stickstoff Syndikat G.m.b.H., which is a long way of writing Nitrogen Syndicate.

The capital stock is held by the Badische Company, which makes synthetic ammonia, the industrial companies who manufacture cyanamid, the German Ammonia Sales Co., and affiliated organisations of the coke works and gas works. The board of directors includes representatives of the Government.

Prof. Caro represents the cyanamide producers ; Dr. Bueb represents the Badische Anilin und Soda Fabrik ; and Geheinrath Bruckner represents the coke ovens concerns.

The most reliable information regarding the output of Germany in 1920 was given in a speech which Prof. F. Haber delivered at Christiania in that year, when he received the Nobel Prize. He said :

> People think that the Norwegian industry may be hurt by my method of making synthetic ammonia. I do not believe it. The world's demand for nitrogen is so extremely great that it can be satisfied only by an intimate co-operation of the different methods. It is impossible that in the near future there will be an over-production of nitrogen, but I do believe the cyanamid industry will come on difficult times. Cyanamid is made from carbide, which has multifarious uses, and now is more used for making other things than cyanamid. As an example I would mention its importance for automobiles. I think its use for that will be because there are not very great quantities of benzine and benzol in the world. Germany is now producing enough fixed nitrogen for its own use and does not need any imports. The German nitrogen production is at the moment a little insecure, as we have not yet the necessary working quietness. But if no political obstacles arise, we shall by my process produce 150,000 tons (metric) of fixed nitrogen this year. Add to that 100,000

tons of nitrogen from coal, and 100,000 tons of nitrogen from cyanamid, and that gives a total of 350,000 tons of fixed nitrogen for the year, which is more than Germany used before the war.

Explosion at Oppau Factory.

On September 21st, 1921, an explosion occurred which killed over 6,000 people and destroyed part of the factory. The destruction has been attributed to a stock of 4,500 tons of mixed nitrate and sulphate ammonia which had set hard and was being blasted at the time. This material did disappear, but there were two explosions and the true explanation of what really happened will probably never be known.

A Parliamentary Committee of Enquiry was set up to find answers if possible to the following questions :—

(1) Is there any evidence of a criminal act ? (2) Was an exceptionally powerful explosive used, and could it have been the cause of the explosion ? (3) Could the use of a large amount of the explosive normally employed have caused the explosion ? (4) Can a normal fertiliser-salt be exploded with the explosive used ? (5) Can a salt of abnormal composition be exploded ? (6) Could such an abnormal salt have been present ? (7) Can a positive answer be given as to the origin of the explosion ? (8) Does the fact that two successive explosions occurred indicate the possibility of another cause, and can that fact be harmonised with the suggested explanation ?

Recently Prof. Wohler has reported that experts gave negative answers to nearly all the questions, including No. 7. They also found that the charge of negligence against the Badische Anilin-und-Soda-Fabrik could not be sustained, as even when every possibility was taken into consideration, such an explosion as occurred could not have been foreseen. The experts recommend that blasting of fertiliser salts containing nitrate be forbidden.

It is probable that the first explosion acted as a detonator to the second, and the first may have been caused by an accidental mixture of hydrogen and air. It can hardly have been caused by the bursting of a catalyst bomb or other vessel due to failure of the steel.

American Plants.

During the war a modified Haber process plant was designed by the American Chemical Co., and erected at Sheffield, Alabama, where it was called Nitrate Plant No. 1. The flow sheet is shown in Fig. 20. It was not a success because there was not enough knowledge available.

The pressure used was 100 atmospheres, and hydrogen was made from water gas by the catalytic method. When the question of ownership of the Mussels Shoals plant is decided Nitrate Plant I. will, no doubt, be redesigned.

Since the war a Haber plant has been built at Syracuse, New York, to make 10 tons of synthetic ammonia per day. It is worked in conjunction with a Solvay process plant.

Synthetic Ammonia and Nitrates Co., Ltd.

In 1918 the British Government did some preparatory work towards establishing a factory at Billingham-on-Tees to make synthetic ammonia on a modification of the Haber process as worked out by Dr. H. Greenwood at University College, London.

After the Armistice it was decided to hand over the completion of the plant and all test records, drawings and patents rights, etc., to a company having the above title to be formed by Brunner Mond and Co., Ltd. All the information and patents of Dr. Maxted and Gas Developments, Ltd., were also purchased.

The company is always to be British controlled and the directors British born, and in case of war it is to be turned over to the Government for production of explosives material, etc.

To gain information of actual running of the process preparatory to large scale working, a small commercial scale unit has been working for some time at Runcorn, in Cheshire. The ammonia is sold as strong liquor.

The works at Bellingham-on-Tees are approaching completion, and are expected to turn out 120 tons of ammonia sulphate and ammonia chloride per day. The site is on the bank of the Tees and included 850 acres, and a river frontage of a quarter of a mile. It is proposed to build wharves capable of accommodating the company's own large cargo steamers, and to extend the plant to a production of 1,000 tons per day.

The company has spent about £100,000 on a fine research laboratory.

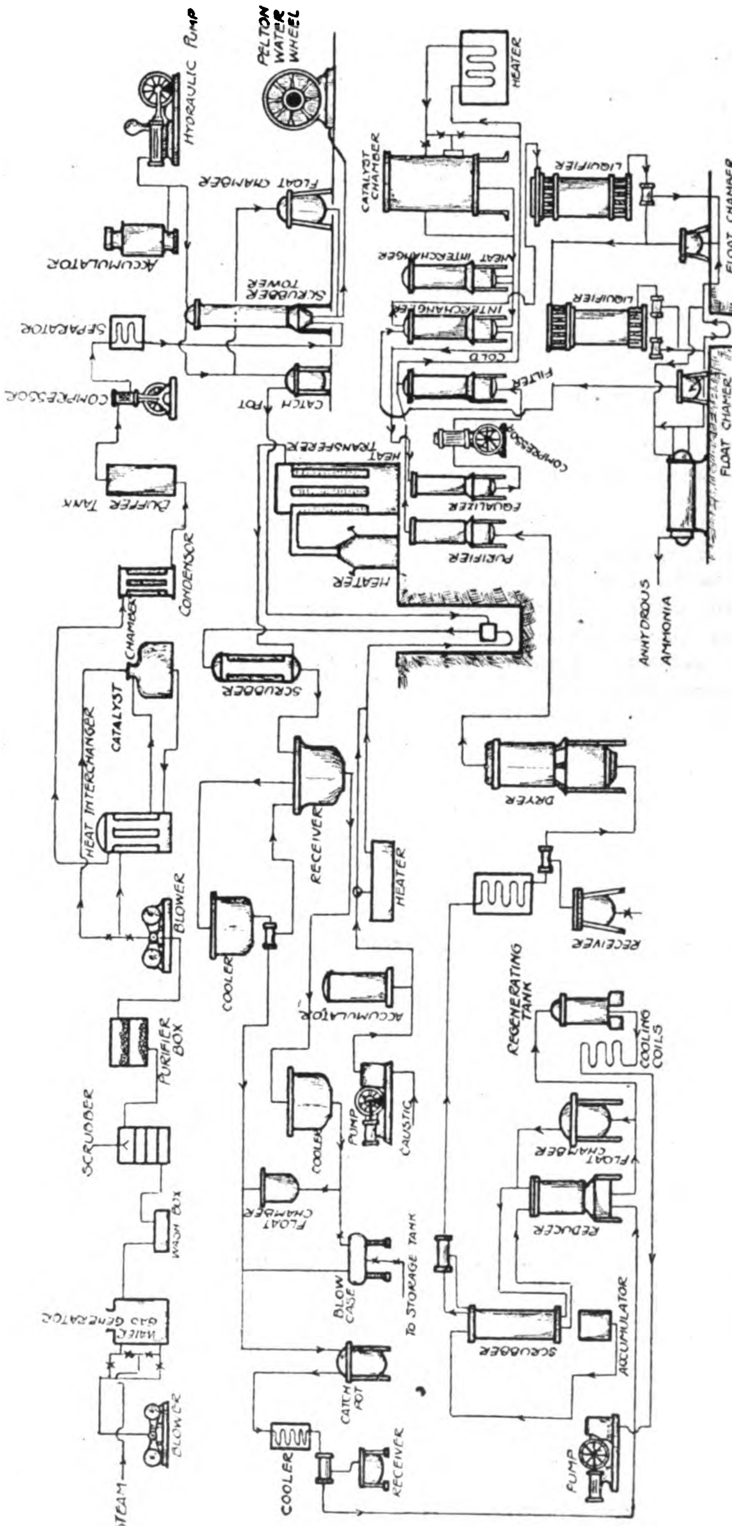

FIG. 20.—Flow Sheet of Synthetic Ammonia.

Flow sheet of synthetic ammonia, American modification by the Haber process at Nitrate Plant No. 1, Sheffield, Ala.

CLAUDE PROCESS.

The name of M. Georges Claude had been known for many years in connection with his liquid air process, when in 1917 he worked on the synthesis of ammonia at much higher pressures than those tried by Naber and Le Rossignol. In this connection it may be mentioned that French engineers have always been to the fore in using high pressure.

In 1882-5 Mekarski used air at 45 and then 80 atmospheres to work street tramcars in Paris, and in 1890 the compressed gas industry began to use 150 atmospheres. In the 30 years from 1890 the limit of pressure was only advanced 33 per cent., and then M. Georges Claude, with typical Gallic audacity, advanced it by over 400 per cent. It was brilliant and it was successful, for he proved that it is possible to construct chemical engineering apparatus satisfactorily to resist 900 atmospheres.

He was partly led to the employment of this very high pressure by knowing that energy required to compress gas increases with the logarithm of the pressure, and thus the expenditure of energy only increases from 2.3 to 3, when the pressure is carried from 200 to 1,000 atmospheres, as shown by the flattened curve of Fig. 21.

PERCENTAGE EQUILIBRIUM OF AMMONIA.

Before M. G. Claude used 900 atmospheres, Prof. Le Chatelier had expressed the opinion that at very high pressure the reaction of nitrogen and hydrogen might be spontaneous, but it was found that a catalyst was still required, although it could, of course, be relatively much smaller than for 200 atmospheres. Claude also found that the useful temperatures of reaction were about the same, namely, between 500 and 700° C.

The most important fact discovered was that the equilibrium percentage of ammonia at 900 atmospheres was much better than was expected by extrapolation from the experimental results of Haber and Le Rossignol.

The curves in Fig. 22 are based on Claude's experiments and it will be seen that results due to great pressures are almost proportional and that with the Haber pressure of 200 atmospheres the percentage of ammonia is 13 per cent., whereas with 1,000 atmospheres, it is 40 per cent.

In actual practice the figures are about 6 per cent. and 25 per cent., but the Claude process recovers 28 per cent. because of the refrigeration by evaporation of the liquid ammonia. I am informed that it amounts to one horse power per hour per 2,500 frigories of cold.

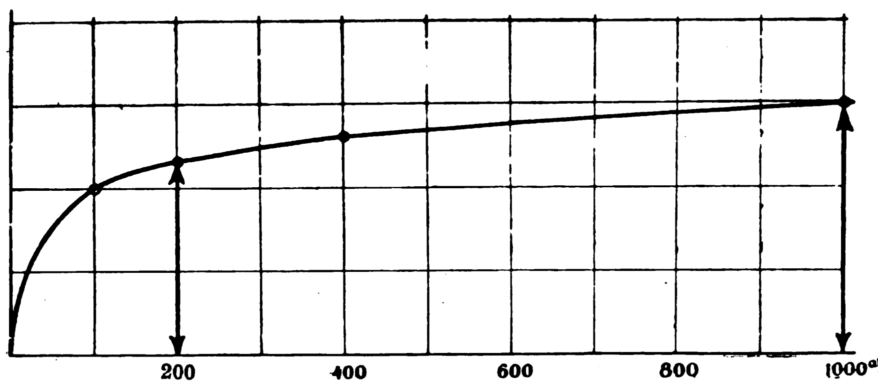

FIG. 21.—Work and Pressure.

This shows how the work of compression increases with pressure, and it will be noticed that the height of the curve for 900 atmospheres, as used by Claude, is not very much higher than for the 200 atmospheres as used by Haber.

The engineering details were worked out by engineers and metallurgists with whom M. Claude is associated, and it is of interest to note that experience in the design and construction of artillery was of very great assistance.

In several commercial plants Claude has demonstrated that with 100 cub. metres of gas per litre of capacity of the catalyser, and per hour he can get 5 kilograms of

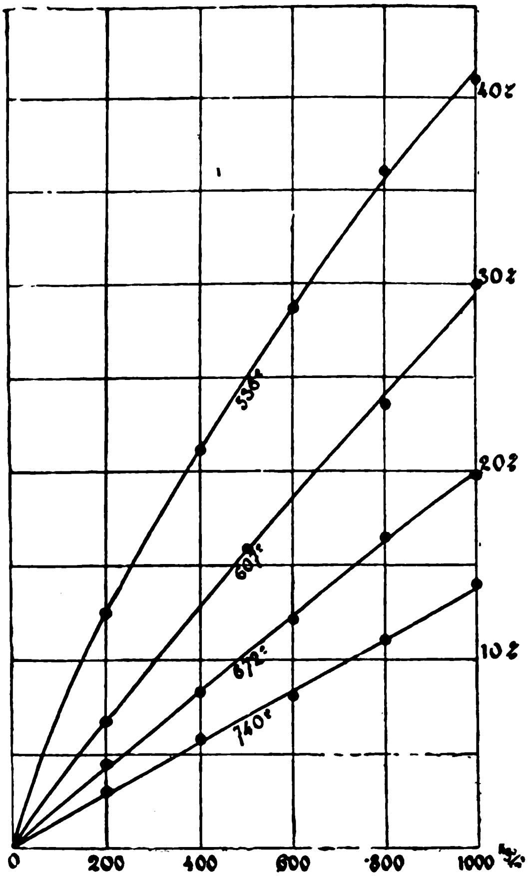

Fig. 22.—Ammonia Equilibrium.

These curves show that the ammonia equilibrium increases rapidly with rise of pressure, and also that the lower the temperature the higher the combination. Claude works at 900 atmospheres and 600° C., and it will be seen this gives an equilibrium of about 28 per cent. The Haber figure is much lower because the pressure is only 200 atmospheres.

ammonia per kilogram of catalyser material instead of 0.5 as obtained by Haber.

Arrangement of Claude Plant.

Fig. 23 shows the layout of the Claude plant as installed at Montereau and at Béthune in France and also Barcelona in Spain.

The hydrogen and nitrogen pass from gasholders A and B through meters CC, where they are mixed in correct proportions by valve D. The mixed gases then pass to compressor E and super-compressor F, by which the pressure is raised to 900 atmospheres. Oil and water are removed by separator G, and the gases then pass through a tube about the size of a man's thumb, to heat interchanger H and protection tube J. This tube removes any traces of carbon monoxide, and oxygen and any water and methane formed is condensed by cooler M, and removed by separator K.

The pure gases now pass through heat interchangers H_2 and H_3 and the first two catalyst tubes L_1 and L_2, which it will be noticed are in parallel. They return via cooler M_2 to the separator N_1, where the liquid ammonia formed is withdrawn. The uncombined gas then continues through heat interchanger H_4 to the third catalyst tube, L_3, back through cooler M_3 to separator N_2, where more ammonia is withdrawn. Finally all the remaining gas goes to the catalyst tube L_4 and back to separator N_3, where more ammonia is removed.

The ammonia collected by the separators N_1, N_2 and N_3 is then blown into the collecting bottle O, and from there to the storage cylinder P.

Hydrogen and Nitrogen.

The method used by Claude for separating hydrogen from carbon monoxide in water gas by means of great cold is shown in Fig. 24. The carbon monoxide and hydrogen gases enter the tubular system by the pipe marked CO and H and pass to the lower ends of the tubes, which are in a bath of carbon monoxide boiling at minus 190°C.

By the action of this bath a large part of the ascending carbon monoxide is liquefied and it falls back into the bottom and passes by a small pipe to a spray which is above the bath and this gradually replaces that which is evaporated.

The remaining gases continue to rise in the tubes and meet with a still lower temperature, which has the effect of liquefying the rest of the carbon monoxide.

Hydrogen leaves the top of the apparatus and enters a small engine in which it expands and is further cooled by so doing. It then passes round the upper ends of the tubes when it produces the very low temperature above mentioned, and finally passes out.

At the Claude plant at Montereau the nitrogen is obtained by burning oxygen out of air. The method is remarkably simple and where there is plenty of hydrogen available it is the best way to get nitrogen as the gas is pure.

Nitrogen can be obtained from the exhaust of the carbon monoxide gas engine, and, of course, it is a bye-product of the manufacture of hydrogen from water gas.

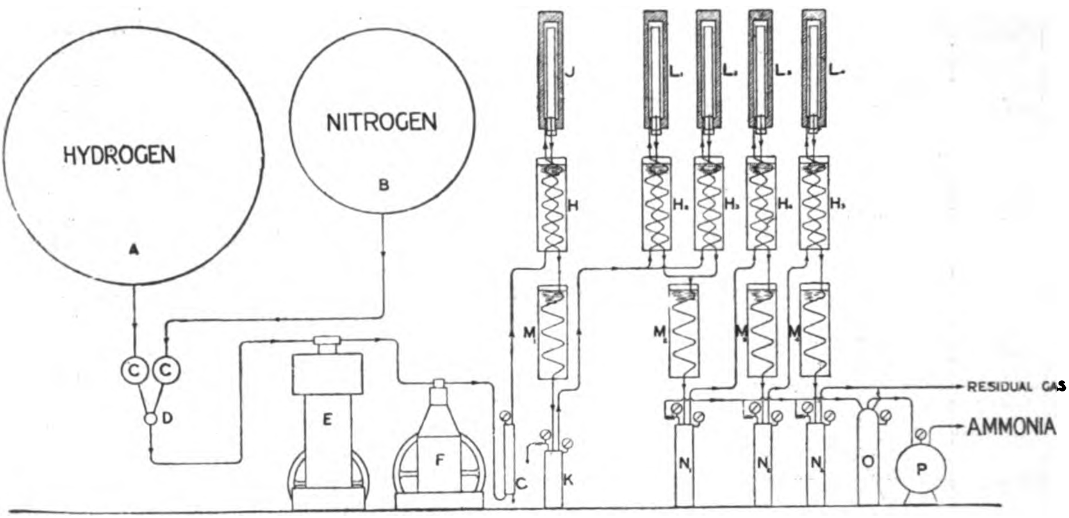

FIG. 23.—Layout of Claude Synthetic Ammonia Plant.

A and B are gas holders, C C the meters, and D is a mixing valve; E is the compressor. F the supercompressor and G a separator of oil and water; H is a heat exchanger; J the protector tube to remove traces of carbon monoxide and oxygen, M_1 a cooler and K separator of water: H_2, H_3 are heat interchangers in parallel, L_1 and L_1 catalyst tubes in parallel, M_2 a heat interchanger and N_1 the separator of liquid ammonia: H_4 and H_5, L_3 and L_4, and M_3 and M_4 and N_3 and N_3 are heat interchangers, catalyst tubes, coolers and ammonia separators in series connection, O is the collecting bottle and P the ammonia storage cylinder.

Super Compression.

The first plant installed at Montereau was for making two tons of ammonia per day with hydrogen from water gas. It had two compressors, the second or super-compressor being of the vertical type with two stages. In the later plant to make five tons per day all the eight stages are combined in one horizontal slow running machine, five stages being on one rod, three on the other rod giving 300, 450 and 900 atmospheres.

The details of design are very clever; and it may be mentioned that the tightness of the glands is secured by means of rings of compressed leather. I was told that they act better as the pressure increases.

This compressor passes 700 cub. metres of gas per hour, and it is driven by ropes from a 300 horse-power engine which works with carbon monoxide gas, which gas is obtained from the water gas plant after the hydrogen has been removed.

The pipes for carrying the gases are relatively very small, for example, a pipe to carry 700 cub. metres of gas per hour sufficient for a 5-ton plant is only the size of a man's thumb.

The tightness of joints depends much more upon dimensions than upon pressure, and the gaseous volume is reduced to such an extent with 900 atmospheres, that the joint is easier to keep tight than one at 100 atmospheres.

Plant at Coke Ovens.

At Béthune in Northern France a Claude plant is worked with hydrogen from coke oven gas which gives 5 tons of ammonia per day. Extensions are being carried out to raise the output to 20 tons per day.

Coke oven gas is more difficult to deal with than water gas, because of the presence of constituents which vary widely in character. The gas at the Béthune coke ovens gives 49 per cent. of hydrogen instead of the usual 54 per cent., and, therefore. 850 cub. metres per hour is treated to give 425 cub. metres, 90 per cent. of which is hydrogen, 1.6 per cent. is carbon monoxide and the rest nitrogen.

The gases from the exit of the benzol extractors are compressed to 25 atmospheres and conveyed into a first column to be freed from remaining benzol by a current of heavy oil circulated by a small pump.

They then pass to a tower in which water dissolves most of the carbon dioxide, the last traces being removed by lime-water injected at the top of the tower. It is

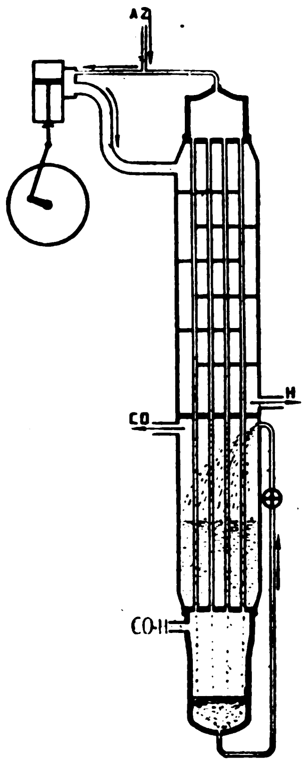

FIG. 24.

The carbon monoxide and hydrogen enter by pipe marked CO and H, and pass to the lower ends of the tubes, where there is a bath of carbon monoxide boiling at 190° C. The hydrogen passes out by the pipe marked H and enters the small engine, in which it expands and is further cooled and it then passes round the upper end of the tubes and produces very low temperature.

important to remove all the carbon dioxide as otherwise it would solidify and choke up the liquefication apparatus.

The compressed gas is progressively cooled and the ethylene and similar hydrocarbons liquefy out, then the methane, then the carbon monoxide, and finally the nitrogen, leaving only the hydrogen in the gaseous state. The nitrogen is liquefied at the top of the apparatus and in running down it washes away the last traces of carbon monoxide.

The hydrogen is allowed to expand whilst doing external work in an engine, and it is thereby cooled to minus 215° C., and subsequently absorbs heat from the incoming coke-oven gas in a heat interchanger. The lubrication of the engine is done by adding a little nitrogen which liquefies in the cylinder. The cost of hydrogen separated in this way is said to be 1*s.* 6*d.* per 1,000 cub. ft.

The hydrogen is conveyed to a gas holder and the other gases which are rich in methane are returned to the works to be utilised. They represent a calorific power of 6,000 calories per cubic metre, and two-thirds of the initial calorific power is thus returned to the coke works. The entire removal of benzol under pressure increases the yield of benzol from 10 to 15 per cent., and the ethylene gives 200 kilograms of alcohol per ton of ammonia product. These pay for the cost of compressing all the gases.

CLAUDE CATALYSER BOMB.

The standard catalyser bomb is 7ft. high, 9in. outside and 4in. inside diameter. It is made of special nickel chrome steel having very low carbon so as to resist occluded hydrogen. It is cast solid, machined and tested for flaws.

Some of the first bombs were made by Vickers, Ltd., of Sheffield, of a special alloy called "Vikro." Mr. Dickenson* head of their research department, has shown that neither Vikro nor any other steel has true tensile strength above a low red heat. The essential property in resisting deformation under stress is the equivalent of viscosity in a fluid. The special advantage of nickel chromium steel is that it has greater resistance to deformation at high temperatures, the rate of flow being a practically negligible amount at a stress of 8½ tons per sq. inch at 500° C.

The head of the bomb is fixed by an interrupted thread like that of the breech mechanism of a gun, and enables the catalyst to be either put in or taken out in eight minutes. The joint is made by a thin copper washer, and the screwing up is done by means of a wormwheel attached to the head, rotated by two worms geared to a crank. When the catalyst has to be changed, rotation of the moveable head by a quarter of a revolution is sufficient.

Cold gases enter at the bottom end of the tube, which assists materially towards keeping the joint tight and as these gases cool the steel it is the better able to withstand pressure.

* See "Flow of Steels at Low Red Heat," read at the autumn meeting of the Iron and Steel Institute. 1922

It has been found that when a catalyser tube does burst the outer layer of metal gives way first, due to transmission of intense heat towards the exterior causing a great fall of temperature. The internal hot layers of metal thus exert great pressure on the exterior layers. As a means of reducing this difference in temperature the outside of the bomb is lagged.

Catalyser Material.

Many substances will give good activity for a short time if pure gases are used, but the practical ideal is to use a catalyst material which will give a long active life under works conditions and with gases which are not technically pure.

Claude catalyser material is made by burning iron in oxygen gas, this oxide being afterwards reduced by the hydrogen of the process. A promoter is also added to increase activity of the synthesis to give immunity from poisons. The material is granular, shiny black in colour and is easy to make and to keep.

As will be seen from Fig. 25 it is packed into an inner tube made of sheet iron and then is covered with a non-conductor of varying thickness. The gases enter cold at A and as they pass upwards to B they take up heat from the reaction from the catalysing material. By the time the gases arrive at the top of the inner tube and pass into the catalyser material they are at about the right temperature, namely, 500° C.

The flood of heat from the reaction is sufficient to give about 60,000 calories per hour. When first starting up from cold the catalyser tube is heated up electrically.

Protector Tube.

A plant to make five metric tons of ammonia per day requires four such catalyser bombs Each bomb weighs 15 cwts., so that for an output of 20 metric tons there would be 16 bombs, which weigh about 12 tons as against the 74½ tons required for a single Haber Bosch bomb for the same output.

A Claude plant has in addition, a protector tube for the purpose of removing any carbon monoxide that may be still left in the hydrogen gas.

This gas is one of the most deadly poisons of catalyser material, and it is very liable to be present in hydrogen made from coke oven gas. With the Claude process as

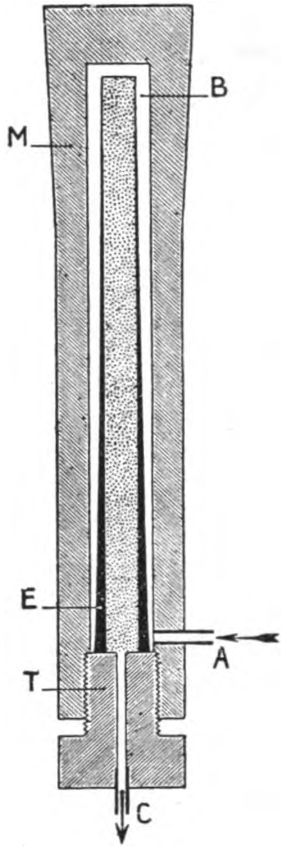

Fig. 25.—Claude Catalyst Bomb.

Made of nickel chrome steel with very low carbon. The movable end has an interrupted screw thread like that of a breech mechanism. It carries a tube filled with catalyst material, which is pure iron with a promoter. The mixed nitrogen and hydrogen gases enter cold, and in passing upwards attain a temperature of about 2,500° C. before passing downwards through the catalyst material.

much as 3 per cent. may still be present before it is finally removed by this protector tube.

It is similar to the catalyser bomb, except that its inner tube is filled with spent catalyst material. This is heated electrically to 400° C. and the carbon monoxide which passes through is converted into methane according to the equation:

$$CO + 3H_2 — CH_4 + H_2O$$

At the same time any oxygen that may be present is burned to water.

All the five tubes are arranged vertically in a housing made of reinforced concrete, which is above ground. There are no special precautions to keep visitors away.

REMOVAL OF AMMONIA.

By using 900 atmospheres it is easy to remove the ammonia because the cooling down of gases by means of coils immersed in water is sufficient to liquefy over 95 per cent. of the ammonia. The remaining ammonia can be removed from the gases by further cooling produced by the vaporisation of part of the ammonia, or by absorption in sulphuric acid. After removal of all the ammonia the uncombined or residual gases return to the system.

It will thus be seen that the procedure is a very simple procedure compared with the Haber system at 200 atmospheres, in which it is necessary to inject water into the system and recover the ammonia as an aqueous solution. This consumes a good deal of power and involves complication of plant, also if the ammonia is required in the anhydrous state the liquor has to be treated.

There is a steady sale at good prices for liquid ammonia for refrigeration, etc., and it is convenient to make it in small lots at a number of centres, and so cut down cost of carriage.

I believe that some day large industrial districts will have synthetic ammonia plant and synthetic nitrate plants for there is a great future in the development of synthetic processes.

COST FIGURES.

The following figures, due to Mr. J. H. West,* give the power required per ton of ammonia made with hydrogen from coke oven gas by Claude process :—

	K.W. hr.	Per cent. of total.
Nitrogen	279	8.53
Hydrogen	1,287	39.35
Compression.. ..	1,530	46.78
Miscellaneous ..	175	5.34
Total	3,271	100.00

* "Claude Synthetic-Ammonia Process and Plant," by J. H. West, *Journal of the Society of Chemical Industry*, November 30th, 1921, Vol. XL., No. 22, pp. 420 R-424 R.

With steam power at 6*d*. per unit, the total cost is £6 16*s*. 3*d*. If the hydrogen were obtained by electrolysis, then 13,590 units would be required, making with the other amount a total of 15,574. At 1/10*d*. per unit this is about £6 10*s*.

As a matter of fact, hydrogen is a bye-product of several electrolytic processes, and the tendency in future will be to use it at these several plants for making synthetic ammonia. I believe that there will be considerable development in U.S.A. in this direction.

WEST-JAQUES HYDROGEN PROCESS.

A Claude plant to make five tons of ammonia per day is being built in Japan, and a contract has been entered into to extend it to 40 tons a day within two years. As local coke is very poor the hydrogen is going to be made by the West-Jaques process of which the following is a description.

This process combines the distillation of coal in a retort and the formation of water-gas from the resulting coke, also the conversion of the carbon monoxide from these operations into carbon dioxide and hydrogen. This is done by reaction with steam in the presence of a catalyst and in one apparatus. The process has the advantage of avoiding the heat and carbon losses incurred by withdrawing hot coke from retorts into the air and quenching with water.

The hydrogen in the crude coal is practically all liberated by passing the crude coal gas through a hot zone in the producer, so that all tar oils and hydrocarbons are cracked or split up into hydrogen and carbon, the carbon reacting with steam to form water gas. It is carried out in a modified form of Tully complete gasification plant, and the only products are gas and ashes.

Mr. J. H. West has had exceptional opportunities of investigating the Claude process, and it may, therefore, be of interest to quote the following opinion :—

"I am thoroughly convinced that the Claude "process in points of low capital costs, simplicity, "and absence of snags is far superior to the Haber."

Much the same conclusion has also been expressed publicly by Mr. H. S. Weeks, F.I.C., head of the chemical research department of Vickers, Ltd.

ELECTROLYTIC HYDROGEN.

At Terni in Italy Dr. Casale has a synthetic ammonia plant in operation which uses a pressure of 500 atmospheres.

The hydrogen is obtained by electrolysis, and it is of interest to note that when made in that way it is very pure, so that the expense of purification apparatus is saved. The oxygen is also pure and the final cost of the hydrogen depends on whether there is a ready sale for the oxygen.

The two kinds of cells used for electrolysis are known as the Filter press type and the Tank type, and the electrolyte may be sulphuric acid or caustic soda. The latter is generally used and it requires 1.69 volts per cell.

Theoretically considered one ampere for one hour should cause the evolution of .0147 cub. ft. of hydrogen measured at normal temperature and pressure, but in actual practice 1,356,170 units of electricity are required for 1,000 cub. ft. of hydrogen and 500 cub. ft. of oxygen.

At £5 per kw. year and on a power consumption of 135 kw.h. per thousand cub. ft. of hydrogen the cost of power is about 1*s.* 7*d.* per thousand cub. ft. of hydrogen.

Dr. E. B. Maxted has stated that if a certain plant takes 10,000 kw. of electric energy, then if the hydrogen is made electrolytically, about 7,500 kw. would be required for that purpose. Also he states that about 1,000kw. would be used for making liquid air to produce nitrogen and 1,000 kw. to compress the gases to 200 atmospheres and circulate them at that pressure. The rest would be used in the motors for auxiliaries.

Such a plant using 10,000 kw. of electricity would produce by the Haber process about 5,000 tons of fixed nitrogen per annum and 33,000 cub. ft. of free oxygen per hour as a bye-product.

In the United States there are a number of concerns producing hydrogen as a bye-product from various electrolytic operations. In some individual cases it is enough to produce two or three tons of ammonia per day, and before long several of them will be producing.

Dr. F. G. Cottrell, Director of the Government Fixed Nitrogen Research Laboratory, Washington, D.C., writes me as follows :—

The actual production would not be specially significant and would all be sold as liquid and hydrous ammonia, for which there is a good and high priced market. It will serve to disseminate knowledge on the subject of ammonia synthesis, gradually train a technical personnel, and give opportunity for experiment and development on a practical scale.

COMPARISONS.

Processes are always more or less in a state of flux, and in making comparisons all that one can say is, that such and such a process appears to have advantages over another in the present state of the art. I think the following may be considered to be a fair summary of the two processes of making synthetic ammonia at the present time :—

HABER.	CLAUDE.
Number of operations.	
A chain of operations at 200 atmospheres, which pressure has to be restored at each step.	A single operation at 900 atmospheres and one compressor.
Condensation of Ammonia.	
Water has to be injected at 200 atmospheres to wash out the ammonia, as a 20 per cent. solution. If liquid ammonia is required it has to be specially liquefied, and if gaseous, then it has to be evaporated.	The ammonia is condensed straight away in the liquid form, and if gaseous ammonia is required it can pass directly into this state.
Gases in Catalyser.	
Nitrogen and hydrogen gases are passed repeatedly over the catalyser material and expensive temperature exchangers are required.	Gases pass in succession through several bombs, and between each pass there are worms to remove the liquid ammonia.
Purification of Gases.	
An expensive gas purifying plant is required to remove the carbon monoxide, etc.	A single protector tube containing spent catalyser material, removes the carbon monoxide.
Size of Catalyst Bomb.	
For an output of 20 tons of ammonia per day there is one bomb 2¾ ft. dia. and 42ft. 8 in. high, weighing 74½ tons.	For a similar output of 20 tons, 16 bombs are required, each 9in. dia. and 7ft. high, their total weight being under 12 tons.

Danger of Explosion. Very considerable because of great size of bomb and large amount of contained gases.	The stresses are less in a number of small tubes and volume of contained gases is only 1/15.
Renewal of Catalyser Material. A long and difficult operation requiring very skilled men. A very large quantity is required.	Very easy, as the material is carried by a steel head having an interrupted thread like a breech mechanism.
Heat of Catalyser. The relatively small amount of heat given off at 200 atmospheres makes it necessary to employ one very large catalyst bomb.	The large disengagement of heat of reaction at 900 atmospheres enables the required temperature of 500° C. to be easily maintained.
Time of Starting. Three whole days are required to heat the system and get started up.	The plant can begin to produce ammonia within five hours.
Size of Unit. About 20 tons per day is minimum size of unit which is commercially feasible.	The unit size of plant can be as low as 2 tons of liquid ammonia per day.

Chemical Equations.

For those who are familiar with chemical equations a comparison of the processes can be written thus :—

(*a*) Synthesis of nitric acid by electric air and explosion processes.

$$N_2 + O_2 = 2NO.$$
$$2NO + H_2O + O = 2HNO_3$$

(*b*) Manufacture of calcium, carbide cyanamid, and ammonia.

$$CaO + 3C = CO + CaC_2$$
$$CaC_2 + N_2 = C + CaCN_2$$
$$CaCN_2 + 3H_2O = CaCO_3 + 2NH_3$$

(*c*) Synthesis of ammonia of Haber and Claude and Casale processes.

$$N_2 + 3H_2 = 2NH_3$$

(*d*) Manufacture of aluminium nitride and ammonia.

$$Al_2O_3 + 3C + N_2 = 3CO + Al_2N_2$$
$$Al_2N_2 + 6H_2O = 2Al(OH)_3 + 2NH_3$$

(*e*) Manufacture of barium carbide and cyanamid and cyanide and then ammonia.

$$BaO + 3C = CO + BaC_2$$
$$BaC_2 + N_2 = C + BaCN_2$$
$$BaCN_2 + C = Ba(CN)_2$$
$$Ba(CN)_2 + 4H_2O = Ba(OH)_2 + 2CO + 2NH_3$$

(*f*) Conversion of ammonia to nitric acid by catalyser. This is common to all processes which give ammonia.

$$4NH_3 + 5O_2 = 6H_2O + 4NO$$
$$2NO + H_2O + O = 2HNO_3$$

(*g*) Absorption of oxides of nitrogen by water to give nitric acid. This is also common to all processes.

$$2NO_2 + H_2O = HNO_2 + HNO_3$$
$$3HNO_2 = H_2O + 2NO + HNO_3$$
$$2NO + O_2 = 2NO_2$$

Haber v. Claude Plant in France.

The annual consumption of nitrogenous fertiliser in France is about 110,000 tons of fixed nitrogen, and the home production is less than one-fifth of that amount. After the war the French Government decided to subsidise a company to build a synthetic ammonia plant at Toulouse to produce about 36,000 tons of fixed nitrogen per annum.

The company's bonds and dividends were to be guaranteed by the Government, and an agreement was entered into between the French Government and the Badische Anilin und Soda Fabrik, by which the company was to sell its rights and technical information and give assistance.

One million francs has been paid on account, but in view of the success of the Claude process the question has arisen whether it is wise to build a Haber-Bosch plant. Some politicians naturally favour a process invented by their own countryman.

The Senate referred the matter to a Committee, who recommended a Commission made up of members conversant with the technical details. Latest reports seem to indicate that the Haber-Bosch plant will not be built at Toulouse.

FERTILISERS FROM AMMONIA.

During the war Germany could not get sufficient supplies of pyrites with which to make sulphuric acid, and, therefore, experts of the Badische Anilin und Soda Fabrik developed a method of making ammonia sulphate from gypsum, which is a mineral form of calcium sulphate $CaSO_4$, $2H_2O$.

It was found that when finely powdered calcined gypsum suspended in a solution of ammonia obtained from the Haber Bosch plant was acted on by carbon dioxide, the calcium carbonate precipitated and a solution of ammonia sulphate formed in accordance with the following equation :—

$$CaSO_4 + 2NH_3 + CO_2 + H_2O = CaCO_3 + (NH_4)_2SO_4$$

The carbon dioxide is a by-product of the manufacture of hydrogen from water gas. The solution of ammonia sulphate is filtered and evaporated in vacuum apparatus.

This process is used at the Leuna factory near Merseburg, Saxony, where such enormous quantities of ammonium sulphate can be turned out as completely to control the central European market.

Ammonia sulphate is much used as a fertiliser and especially for such crops as rice. It usually sells at a lower price per unit of contained nitrogen than any other fertiliser. Those who wish to study the question I would refer to papers by Dr. E. J. Russell,* Director of the Rothamsted Experimental station.

Ammonia Chloride.

Ammonium chloride is one of the coming fertilisers because it can be made cheaply, along with bicarbonate of soda by the Solvay Ammonia Soda process. This will probably be the method of using some of the ammonia made at the Bellingham-on-Tees plant.

The strength of usual salt solution of natural Cheshire brine is rather less than saturated, and under that condition only sodium bicarbonate is precipitated, the ammonium chloride with one-third of the original salt remaining in solution. From this solution, obtained by filtration of the carbonated brine, the salt and ammonium chloride can be separated by crystallisation.

M. G. Claude uses brine which contains about 36 parts of salt per 100 parts of water at the ordinary temperature. It is saturated with ammonia gas and then carbon dioxide (recovered when making hydrogen) is passed into the ammoniacal brine under pressure. Decomposition takes place and ammonia chloride, NH_4Cl, and sodium bicarbonate, $NaHCO_3$, are formed thus :-

$$NaCl + NH_3 + H_2O + CO_2 = NaHCO_3 + NH_4Cl.$$

The reaction is reversible, and a state of equilibrium is reached when about two-thirds of the salt are decomposed. Sodium bicarbonate is sparingly soluble in water, and even less so in a solution of common salt, and it is therefore precipitated in the form of a white powder. The operation is carried out in towers provided with cooling pipes through which cold water circulates.

Another modification, due to Schreib, is to saturate the filtrate from a bicarbonate with common salt, adding a further quantity of ammonia and again treating with carbon dioxide, when ammonium carbonate $(NH_4)_2CO_3$, is formed. By further addition of carbon dioxide, ammonium bicarbonate is formed, which precipitates sodium bicarbonate, and leaves ammonium chloride in solution :

$$NH_4HCO_3 + NaCl = NaHCO_3 + NH_4Cl.$$

By the addition of more salt and ammonia, the cycle of operations is begun again or the same solution may be used indefinitely. It is necessary to add solid salt to bring the solution up to strength.

High Nitrogen Fertilisers.

There is also a considerable future for double fertiliser salts, which contain nitrogen and phosphorus or potash. In Germany a double salt of ammonia nitrate and ammonium sulphate, which is used for fertiliser purposes, has the composition:

$$(NH_4)_2SO_4 \; ; \; 2NH_4NO_3$$

It is prepared by crystallization and is less hygroscopic than the ammonium nitrate from which it is made. Its agricultural value is said to be excellent.

Another double salt is ammonium chloride and potassium nitrate, obtained by double decomposition by mixing thus :

$$NH_4NO_3 + KCl = NH_4Cl + KNO_3$$

It is valuable because it contains the two plant foods, nitrogen and potash, and is

* See "Artificial Fertilisers : Their Present Use and Future Prospects," *Journal of the Society of Chemical Industry*, March 15th, 1917. Vol. XXXVI., pp. 250-261.

non-hygroscopic enough for fertiliser purposes.

For some crops it is better to have ammonia sulphate instead of ammonia chloride and a mixed salt can be made thus :

$$2NH_4NO_3+K_2SO_4=(NH_4)_2SO_4+2KNO_3$$

The Badische Anilin und Soda Fabrik make it by treating ammonium with carbon dioxide from flue gases, thus :—

$$NH_3+CO=H_2O+CO \quad (NH_2)_2$$

Urea will be one of the best fertilisers when it can be produced chemically at a cheap enough price per unit of contained nitrogen. It contains 47 per cent. and the crystals are long needles and not deliquescent.

Oxidation of Ammonia.

Another way in which ammonia may be used is to change it into a nitrate and thus into a quicker acting fertiliser. This is done by oxidation in the way first discovered in 1830 by Kuhlman. He noticed that when a mixture of an ammonia was passed over heated platinum sponge, red fumes of nitrogen oxides were given off.

Prof. Oswald, of Germany, developed a commercial process, and secured patents in every important country except his own, the reason of rejection there, being the previous - work done by Kuhlman and others.

The Ostwald converter consisted of a vertical tube of nickel placed within a tube of enamelled iron, in which the air ammonia mixture passed at the bottom. The catalyst was a roll of platinum foil about 2 c/m wide coiled up in the mouth of the nickel tube. The hot gases preheated the incoming air ammonia mixture outside.

A type developed during the war consists of a water cooler aluminium box with baffles for distributing the incoming mixture of air and ammonia. It is surmounted by a conical hood of aluminium, which has a mica window.*

The catalyst consists of a layer of platinum gauze made of 0.065 m/m diameter wire woven to give 80 meshes to th: inch. It is fitted with silver leads for electrical heating and fixed in an aluminium frame between the base and the hood.

Various small plants to oxidise ammonia were erected in England during the war, notably at Dagenham Dock, by Nitrogen Products and Carbide Company, and at Widnes by the United Alkali Company. The largest in the world was built at Mussels Shoals, Ala., and is described in Lecture II.

In normal times the process is handicapped by the fact that the price per unit of nitrogen is about the same, whether it is in the ammonia nitrogen form or the nitric nitrogen form. Therefore, commercially there can be no gain in making the change, for, of course, there is a loss in the conversion and the plant is expensive, especially the platinum catalyst.

It may be mentioned that the chief source of platinum is in the Ural mountains in Russia, and therefore any process which depends on this metal is considerably handicapped by uncertainty of supplies. It was a touch and go business during the war, when Russia collapsed. It would be unwise to depend on this rare metal in case of future trouble.

RESEARCH AND DEVELOPMENT.

Extensive researches into problems of nitrogen fixation were going on in Germany for many years before the war, and those of Professors Haber and Ostwald have been referred to. Several firms were also at work for many years before the war.

In 1913 the Badische Anilin und Soda Fabrik built a laboratory at the Oppau synthetic ammonia factory, 300ft. long by 100ft., and eight storeys high, which cost £150,000. During the war a staff of 215 experts was kept continuously at work and even after it was over, representatives of the Allies who visited the plant found 75 expert chemists and engineers still patiently at work.

In the United States a research on the Haber process was started in 1915 by the Bureau of soils, and it was continued by the Nitrate Division of the Ordnance Department after America came into the war. In 1919 a Fixed Nitrogen Research Laboratory was established at Washington, D.C., and it is now under the Department of Agriculture. The Director is Dr. F. G. Cottrell, and he has a staff of 115 assistants, and the annual budget is over £50,000.

Of course, in Norway a number of engineers and chemists are always busy, investigating modifications of the arc process, and the same may be said of Switzerland.

* See "Oxidation of Ammonia," by C. S. Imison, B.A., and W. Russell, B.Sc., *Journal of the Society of Chemical Industry*, February 28th, 1922. Vol. XLI., No. 4, pp. 37T-45T. Also a paper by W. S. Landis read before the American Electro-Chemical Society, April 3rd, 1919.

These countries are naturally concerned in utilisation of bulk water power.

In France, M. Georges Claude and his assistants, besides several other scientists, are always at work. Drs. Casale and Pfauser and Mr. C. Rossi also help to keep Italy well to the fore in nitrogen fixation.

Japan, which has been referred to already as having adopted the Claude process, is always on the *qui vive* for new improvements. So much is that the case that Japan may be almost taken as a barometer of scientific and engineering advancement. If the Japanese Government or the Mitsui Company takes up anything it can be safely assumed to be the latest and the best.

Research in Great Britain.

And now let us see what we have done and are doing. The arc process of fixing atmospheric nitrogen was the outcome of the philosophic research work of Priestley and Cavendish, followed by the more utilitarian investigations of Rayleigh, but practically all the development work has been done abroad, largely in Norway, Austria and France.

Various researches of Davy, Faraday, Perkin, Ramsay and Young, etc., resulted in the establishment of industries in Germany, more or less connected with fixation of nitrogen.

Preceding the war Dr. E. B. Maxted and myself were about the only ones doing any research in nitrogen fixation in this country. Some of us saw war looming ahead and knew the danger of relying on overseas supplies of Chili nitrate for explosives and the costliness and wastefulness of treating it with sulphuric acid, also largely dependent on overseas supplies of pyrites.

Dr. Maxted's work was principally on the direct synthesis of ammonia, and previous to his papers little was known in this country of the actual yields in the presence of promoted iron catalysts, which are the catalysts actually used for the synthesis of ammonia.*

After war did break out practically nothing was done for the first two years, and even then it only took the form of a research at University College, London. Eventually in May, 1918, it was decided that the Explosives Supply Department should build a plant and regarding this Drs. Partington, M.B.E., and L. H. Parker, M.A., make the following comments in their book,† "The Nitrogen Industry."

> The plans of the National Factory were to be drawn up by Mr. K. B. Quinan, the technical adviser to Lord Moulton. Mr. Quinan had, unfortunately, no theoretical or practical knowledge of the fixation of nitrogen, and for other reasons nothing had been done at the time of the Armistice beyond the acquisition of the site at Bellingham-on-Tees admirably exposed to Zeppelin attack.

After the war the apparatus at University College was dismantled, which was nothing more or less than sabotage. So far as general research of the nitrogen problem in this country is concerned, we are thus in the same position as before the war. A few are working privately in pigeonholes, as it were, and there is a complete lack of helpful co-operation.

I think this country should have a a nitrogen research department something like that at Washington, D.C. Failing that, I think there might be an institution where researches could be carried on by a scheme of Fellowships as is done at the Mellon Institute, Pittsburg.

Empire Developments.

Nitrogen fixation is as much an Empire matter as building new fighting ships and dockyards in which to berth them at strategic points. It is as much an Empire matter as having periodical conferences to discuss emigration problems and finance. It is as much an Empire matter as encouraging the cultivation of rubber or cotton or wheat in various parts of the Empire. All these supplies and all food supplies depend ultimately on cheap fixed nitrogen.

I know that our people in the Dominions expect the old country to keep in the van of engineering and chemical progress, not necessarily in having large plants, for mere bigness does not matter, but in initiating new processes and keeping them up to date.

During the last century, particularly about the earlier part of the Victorian era, we led the world in engineering achievement and in developing new scientific ideas. To-day it is different for a study of the moving engineering and chemical products will show that in a surprisingly large number of cases the pioneer researches done in this

* See "Ammonia Synthesis Catalysts and Plant," *Chemical Age*, 1919, Vol. I., p. 515.

† *The Nitrogen Industry*, published by Constable & Co., in 1922.

country have received their actual final development abroad.

It is our business to develop all the resources of the Empire, and there is much to be done. There are great natural water powers running to waste equal to anything in Norway, Switzerland or America; there is power of existing irrigation dams and of others that are contemplated. There are coalfields where fuel can be mined at a fraction of what it costs in Great Britain. There are great stretches of territory which need agriculturalists who know the chemistry of fertilisers and understand intensive cultivation by irrigation. We have the greatest potential granaries of the world.

We ought to be getting ready for these developments by having plants in this country in which the personnel can be trained, where new ideas can be given a fair trial and where improvements can be made to various processes. Other countries with less at stake are doing this, so why not Great Britain?

In conclusion, I think I cannot do better than quote the following, from a paper read recently by Mr. W. Wilson, M.Sc.:—

Electrical engineering generally has been founded chiefly on the brilliant work of great British electricians, such as Faraday, Maxwell, Kelvin, Hopkinson and Thompson, yet much of the work of application and development has been carried out in America and on the Continent, while quite a considerable proportion of the apparatus actually manufactured in this country during recent years has been made to designs supplied from abroad. . . . . We have grown accustomed to abandoning our enterprises just where they begin to be profitable. By permitting foreign nations to act before us in this manner we are conceding them the initiative, *an error in tactics as serious in commerce as in war*. In the Colonial and foreign fields the effect of this loss of initiative is especially evident, for prestige is there an important factor in determining success.*

* See "Industrial Research with special reference to Electrical Engineering Development," read in October, 1923, before Institution of Electrical Engineers.

NOTES ON BOOKS.

ARCHITECTURAL EDUCATION A CENTURY AGO. By Arthur T. Bolton, F.S.A., F.R.I.B.A. London: Sir John Soane Museum. 1*s*.

This pamphlet, which forms number 12 of the publications of the Sir John Soane Museum, gives an account of the pupils and assistants of Sir John Soane, with special reference to the career of his most distinguished pupil, George Basevi (died 1845), architect of the well-known Fitzwilliam Museum at Cambridge. The method of the education of the architects of the time is fully explained and the illustrations, from original pencil drawings made in Italy and Greece by Basevi in 1817-19, are fine examples of draughtsmanship. Particulars of the lives and works of some fifty-five members of the office of Sir John Soane are given, making a valuable record of the transitional period during and after the great war of the French Revolution.

DESIGNS FOR ARTISTIC LEATHER WORK. Elementary Part I. By Ellin Carter. London: E. & F. N. Spon, Ltd. 2*s*. 6*d*. net.

About two years ago a note appeared in these columns of Mr. Carter's "Designs for Artistic Leather Work." In response to enquiries from teachers for more simple designs suitable for beginners and children, he has now compiled this booklet, which contains twelve pages of easy subjects, intended to train the pupil in curves, careful and exact treatment of forms, such as stems of plants, the overlapping of lines, etc., and also for more advanced study a grouping of massed leaves and flowers, and berries and leaves, thus giving scope for gradation of work. The subjects seem to be well adapted for this purpose, and should prepare the young student to proceed to the author's more advanced text book.

NON-INTOXICANTS. Edited by Carl A. Nowak. St. Louis, Mo. C. A. Nowak, Publisher, Chemical Building.

NEW FIELDS FOR BREWERS. Edited by Carl A. Nowak, St. Louis, Mo. C. A. Nowak, Publisher, 2027, Railway Exchange.

New Fields for Brewers comprises 300 pages in which are detailed numerous schemes and suggestions for making use of the establishments, plant and staffs of the brewers during times of "National Prohibition"; the suggestions are widely various, and as examples we may mention malt flour, extracts, and diastase pastes; dried fruits, syrups and aerated beverages; while on p. 288 one may find nearly half a page of small type devoted to a scheme for preparing food from wood.

Non-Intoxicants seems to be the companion volume which is half promised on p. 13 of *New Fields for Brewers*; and this later volume deals so thoroughly with the leading aspect, *i.e.* "Soft Drinks," to use an American term, as to make it a quite comprehensive text book on non-alcoholic drinks.

The two works are well worth preservation on this side of the Atlantic for occasional reference or study; one notable point of interest being the light cast upon what may be regarded rather as sophistication of dietetic materials than adulteration. As an example of this, we may refer to the use of chemical preservatives in non-intoxicant

drinks, but perhaps the most undesirable of all these chemical preservatives is hydrofluoric acid (p. 60.). Such precautions as are suggested appear unsatisfactory.

Phosphoric acid is mentioned frequently as an acidulant, and as the cruder commercial grades of phosphoric acid are cheap it seems now to be much used not only in drinks as a substitute for citric acid or tartaric acid, but also (as an acid salt) in baking powders and mixtures sold as self raising flours. Quite apart from any question of danger from over dosing with phosphoric acid, the commercial acid frequently contains so much arsenic as to be a possible or probable danger. The British Pharmacopœia of 1914 recognises the presence of more or less arsenic in commercial phosphoric acids, and on p. 20 defines a standard of purity or "arsenic limit" for phosphoric acid used in dispensing; and the medicinal dose of phosphoric acid, as stated on p. 21 is approximately from half a grain to two grains of the actual acid; a dose which may be much exceeded in drinking a "soft drink" acidulated with phosphoric acid or eating pie crust prepared from flour admixed as suggested above. Ordinary food, or food in the old-fashioned or non-chemicalised sense, contains, we believe, enough oxidised phosphorus for the needs of average persons, and any special increase required by an individual should naturally be under the control of that individual's medical adviser. If phosphoric acid and the other chemical medicaments mentioned in this book are to be supplied at random, and without notice, in chemicalised dietetic materials, medical men may be misled and grave results may flow. One value of the two books now under notice is that they give hints as to what it may be expedient to look for or expect in foods, as sold in our time.

THE EXPERT WITNESS. By C. A. Mitchell, M.A., F.I.C., Cambridge: W. Heffer & Sons, Ltd. 7*s.* 6*d.* net.

The expert witness has long been the butt of the humorist, and, as some of the instances quoted by Mr. Mitchell show, ground has not been wanting in the past for the popular belief that the evidence of the expert witness is not unaffected by the question from which side he receives his fee. With the steady growth of science in precision, however, distrust of the expert witness is rapidly disappearing; and although the ordinary British juryman is still at times inclined to suspect evidence which he cannot understand, he is less shy of scientific terms and data than were his fathers and grandfathers before him. Mr Mitchell himself has done much to bring about this change: he is well known in the law courts (particularly as an expert on hand-writing), where his evidence always carries great weight; and the paper on this subject which he read before the Society last February, and his course of Cantor Lectures on "Inks," have made his name familiar to all readers of the *Journal.*

One of the most interesting chapters in the book is that in which he deals with the evidence of identity, and in this chapter one of the most interesting cases is concerned with two negroes, both named Will West, and both confined in the United States Penitentiary at Leavenworth, Kansas. The photographs, full face and profile, of these two show that they are so extraordinarily alike that it was almost impossible to distinguish one from the other. Their finger prints, however, which are reproduced in the book, were strikingly different, and these photographs afford a valuable proof of the importance—we had almost said, the infallibility—of skin prints as a means of identification. In this connexion one may perhaps quote a couple of sentences from Mr. Mitchell:

> "When Jezebel was thrown to the dogs, and they went to bury her, they found no more of her than the skull and the feet and the palms of her hands, so that no man could say: 'This is Jezebel.' But, as Sir Francis Galton remarked, it was by the soles of the feet and the palms of the hands, and by them alone, that it would have been possible to identify the body of Jezebel with absolute certainty."

Other branches discussed by Mr. Mitchell treat of the evidence of the medical man, the chemist, the bacteriologist, the expert in handwriting, and the expert in art. In the last connexion the author quotes the famous or, rather, farcical case of Whistler *v.* Ruskin, when the late W. P. Frith was called as an expert witness to assess the value of Whistler's "Battersea Bridge" and "Nocturne." The moral to be drawn from this chapter seems to be that, great as may be the value of the expert witness on scientific points, which ought to be matters of fact, on artistic points, which are so often matters of opinion, his evidence is apt to be extremely dangerous.

Mr. Mitchell's book is rich in references to interesting cases, and is written in a style that will appeal to the layman as well as to the legal profession.

GENERAL NOTE.

FOREST RESOURCES OF THE WORLD.—A comprehensive work entitled "Forest Resources of the World," consisting of two volumes of about 1,000 pages in all and containing a discussion of the general forest situation of the world and the forest resources of each country, has recently been published. Questions such as those relating to forest areas, standing timber, character of ownership, character of forests, annual cut, annual growth, domestic consumption, and export trade, together with the future outlook and other important subjects, have been treated under the respective countries. The authors are Messrs. Raphael Zon and William N. Sparhawk, forest economists of the Forest Service of the United States Department of Agriculture, and internationally known as experts in their line. This publication has been prepared under the authority of the Secretary of Agriculture of the United States.

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